CHEMICAL ENGINEERING 04 SOLIDS SAMPLING AND FLOW • CLEAN-IN-PLACE SYSTEMS VOL. 125 NO.4 APRIL 2018

CHEMICAL ENGINEERING

ESSENTIALS FOR THE CPI PROFESSIONAL

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April 2018

Clean-in-Place Systems

Lithium Processing for Batteries

Level Measurement

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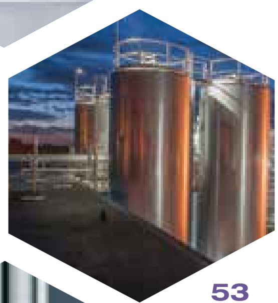

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Cover design: Rob Hudgins

CHEMICAL ENGINEERING
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Editor's Page

Making connections

Most of us involved in the chemical process industries (CPI) are familiar with — to varying degrees — the industrial internet of things (IIoT). Also known as Industry 4.0 and more recently as industrial digitalization, the movement toward connecting more and more aspects of industrial plants is being enabled by tools that are becoming available at an ever increasing pace. It can be a chore to keep up with the latest developments, and particularly, how they might relate to the CPI. The recent Connected Plant Conference (February 26–28, 2018; Charlotte, N.C.; www.connectedplantconference.com) provided a resource for this information in one place. Professionals from the chemical process and power generation industries convened to take a deep dive into digitalization within their respective industries.

The Connected Plant Conference

Attendees heard from both users and vendors, who shared information about the latest tools and how they are being implemented. Both success stories and "learning experiences" were shared. For example, the use of drones to help create impressive 3-D images of hard-to-access places that can be used to check maintenance needs was demonstrated. Practical information about what is actually needed to fly drones and prevent crashing, based on some initial failures, was also shared.

The economic aspect of how to make the business case for digitalization was addressed by a number of speakers. Craig Harclerode with OSIsoft Inc. drove the point home when he talked about the "4M" or "Make Me More Money" approach. That phrase resounded with several speakers.

Diving into big data analytics was the topic addressed by Yves Gorat Stommel, with Evonik Corp. Stommel presented the approach his company took, which involved starting with a predictive maintenance application. This, he explained, is seen as a learning process and entry point into advanced analytics, which can lead to bigger goals like process optimization. He elaborated on how the technological, organizational and economic questions surrounding change and implementation of new technologies can lead to gridlock and slow or no progress, and that it is necessary to accept some uncertainty in the initial steps and investment.

Vince Ward, with The Dow Chemical Company, discussed choice and implementation of mobile devices. Improvements in data entry accuracy and efficiency, the ability to access operational information when needed, safety upgrades such as with personnel location and monitoring, as well as faster training with digital instruction were all cited as advantages of going digital.

The human side of digitalization

While much attention was given to the technologies of digitalization at the conference, the human side was also addressed. Sree Hameed from Schneider Electric Software spoke of addressing structural problems and the importance that the work process and culture play in achieving our goals. He quoted General Colin Powell who said, "Endeavors succeed or fail because of the people involved."

In addition to learning about digital connectivity, attending the Connected Plant Conference offered the chance to make connections with people, who are ultimately the drivers for success. ■

Dorothy Lozowski, Editorial Director

Retrofit unit boosts ethane and propane recoveries in natural gas plants

Edited by:
Gerald Ondrey

Using a workhorse technology known as the gas-subcooled process (GSP), most natural gas plants recover between 85 and 90% of ethane in raw natural gas streams. Honeywell UOP (Des Plaines, Ill.; www.uop.com) has developed a modular retrofit unit designed to be installed on existing GSP units that boosts the recovery of ethane and propane from natural gas to 99% or higher.

Higher levels of ethane and propane recovery translate to extra profit for gas processors, who can sell the additional recovered ethane as feedstock for ethylene production and the additional recovered propane as feedstock for propylene production, rather than surrendering it to be burned as fuel, as it is in the conventional process.

The standard extraction of natural gas liquids (NGLs; mostly ethane, propane and butane) from natural gas involves condensing the NGLs from the gas stream using auto-refrigeration mechanisms and using distillation columns to separate the different NGLs. Refrigeration is achieved through the Joule-Thompson effect (using a pressure drop to allow gas to expand, creating a cooling effect) via a turboexpander, which removes heat as high-pressure gas expands. Depending on the richness of the feedstock, additional refrigeration using propane may also be utilized.

The new high-recovery retrofit unit piggybacks on the conventional approach, but

UOP

adds an advanced process cycle that leverages residue gas vapors as an additional reflux for a new side column (diagram). The side column effectively extends the length of the existing demethanizer distillation column, allowing more ethane to be extracted from the residue gas and separated, explains Craig Ranta, business director for gas processing at UOP.

The pre-engineered unit is available as a drop-in retrofit package, but is also customizable to meet end-user specifications and equipment. The modular, skid-mounted approach facilitates installation and minimizes plant downtime, Ranta says, and payback on the capital investment can be realized in less than one year.

UOP's first commercial retrofit unit is currently under construction and will start up at a customer site in the second quarter of 2018.

These batteries can handle the cold

Lithium-ion batteries based on intercalation compound electrodes exhibit poor performance at temperatures below 0°C. Insufficient ionic conductivity and freezing of the electrolyte are generally seen as the main reasons for the poor performance of rechargeable batteries at low temperatures. Although several attempts have been made to solve this problem, those attempts involved additional materials that added extra weight, which is detrimental for portable devices.

Now a team from Fudan University (Shanghai, China; www.fudan.edu.cn) has developed an ethyl acetate-based electrolyte that exhibits sufficient ionic conductivity at –70°C. Ethyl acetate was a promising choice due to its low freezing point of –84°C, but the low-temperature performance of ethyl acetate electrolyte had never been investigated previously.

For the electrodes, the team used two organic polymers: a polytriphenylamine (PTPAn) cathode; and a 1,4,5,8-naphthalenetetracarboxylic dianhydride (NTCDA)-derived polymide (PNTCDA) anode. Unlike the electrodes used in Li-ion batteries, these organic compounds do not rely on intercalation — the process of integrating ions into the electrodes' molecular matrix.

The team noted that their battery offers several other advantages. "Compared to the transition-metal-containing electrode materials in conventional Li-ion batteries, organic materials are abundant, inexpensive and environmentally friendly," says team member Yongyao Xia. He estimates the price of the team's electrode materials at about one third that of the electrodes in a commercial Li-ion battery.

More work will be required before the new battery can be commercialized, however. The specific energy (energy per unit mass) of the new battery is still low compared with commercial Li-ion batteries, and the assembly process needs to be further improved.

WASTE TO CHEMICALS

A consortium of companies, including Air Liquide (Paris, France; www.airliquide.com), AkzoNobel Specialty Chemicals (Amsterdam, the Netherlands; www.akzonobel.com), Enerkem Inc. (Montreal, Canada; www.enerkem.com) and the Port of Rotterdam, has signed a project development agreement covering initial investments in an advanced waste-to-chemistry facility in Rotterdam, the Netherlands. The facility will be the first of its kind in Europe to provide a sustainable alternative solution for non-recyclable wastes.

An initial €9-million investment covers detailed engineering, the setup up of a dedicated joint venture (JV) and completing the permitting process. The consortium aims to take the final investment decision (FID) for the estimated €200-million project later this year and has appointed Dutch Rabobank as the lead advisor for the financing process.

The facility will convert up to 360,000 tons of waste into 220,000 tons (270 million L) of methanol. The facility will be built within the Botlek area of the Port of Rotterdam using Enerkem's proprietary bubbling fluidized-bed gasification technology, and will convert non-recyclable mixed waste, including plastics, into synthesis gas (syngas), which is then used for making methanol. The plant will have two production lines, or twice the input capacity of Enerkem's commercial-scale plant in Edmonton, Canada (*Chem. Eng.*, October 2010, p. 14).

SELF-HEALING TIRES

Arlanxeo B.V. (Maastricht, the Netherlands; www.arlanxeo.com) has developed a rubber compound

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that can be used in the future to seal tires. Applied to the interior of automobile tires, the material automatically seals any holes that might form due to a nail or other sharp object. The company says the development will eliminate the need for spare tires and the associated tools in cars, which would lead to a significant weight reduction, especially for electric vehicles.

Following successful laboratory trials, the company is now performing further durability tests under extreme conditions, and plans to launch the compound sometime later this year.

COMPOSITE LAMINATES

Saudi Basic Industries Corp. (SABIC; Riyadh, Saudi Arabia; www.sabic.com) has invested in the composite industry's first automated, digital system for the large-scale manufacture of laminates made with its continuous, fiber-reinforced thermoplastic composite (CFRTC) tapes. The Digital Composites Manufacturing system — an automated and digitized production line developed with Airborne International B.V. (Den Haag, the Netherlands; www.airborne.com) and powered by Siemens AG (Munich, Germany; www.siemens.com) — is slated to go live in early 2019.

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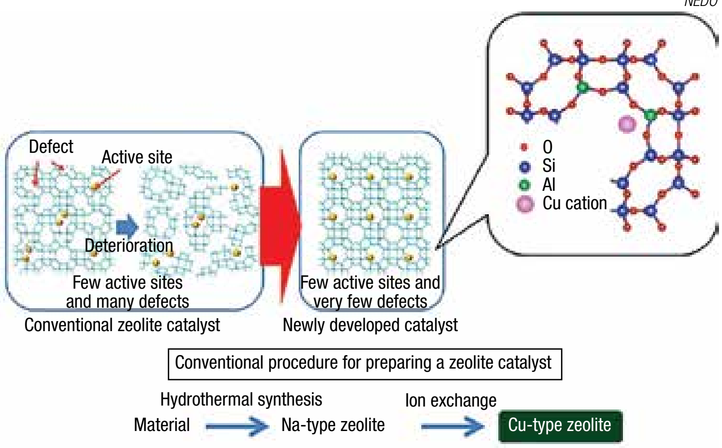
Improved deNOx zeolite catalyst promises to reduce fuel consumption



In a project of the New Energy and Industrial Technology Development Organization (NEDO; Kawasaki, Japan; www.nedo.go.jp), a collaboration of six industrial, government and academic partners has developed a catalyst for reducing oxides of nitrogen (NOx) from automobile exhaust. Because the catalyst operates at both low and high temperatures (for example, during startup and normal running), the achievement may lead to a "dramatic improvement in fuel consumption," says NEDO.

Two innovations were key to the development: an ultra-fast process for synthesizing zeolites, and a method for producing fine particle powders.

The University of Tokyo, National Institute of Advanced Industrial Science and Technology (AIST) and Mitsubishi Chemical Corp., developed the optimized Cu-type zeolite catalyst using an ultrafast procedure to introduce Cu into Na-type zeolites. The procedure uses two flow-reactor systems for mixing liquids to quickly generate a zeolite structure while reducing structural defects "to the utmost limit" (see also *Chem. Eng.*, January 2017, p. 11). The reactor system requires only tens of minutes to as little as 6 s, compared to several days to weeks needed for conventional zeolite synthesis methods.

The Industrial Technology Center of Tochigi Prefecture and Ashizawa Finetech, Ltd. developed a scalable technology for fabricating fine powders while suppressing the formation of amorphous zeolites. Their technology, which combines continuous bead mills and other machinery, enables full control of the particle-diameter density of active sites. The Fine Ceramics Center and AIST contributed to the clarification of the reaction mechanisms and how that relates to catalytic performance and its degradation.

The new catalyst is highly active at low temperatures and remains highly active and durable, even after undergoing high-temperature durability testing. This catalyst is therefore suitable for use at temperature zones in which conventional catalysts do not function.

Gas sensors get a big boost in sensitivity

It has been a challenge to find materials that can reliably detect volatile organic compounds (VOCs) and toxic gases in air at the parts-per-billion (ppb) level, or that can be used for therapeutic diagnosis from breath analysis. That's because two requirements must be simultaneously met to obtain very high sensitivity in typical resistive sensors: low electrical noise, due to high conductivity; and high signal, due to strong and abundant analyte-adsorption sites. These two requirements are, however, usually in a trade-off relationship.

Now researchers from Drexel University (Philadelphia, Pa.; www.drexel.edu) and the Korea Advanced Institute of Science and Technology (KAIST; Daejeon; www.kaist.ac.kr) have demonstrated that a 2-D, titanium-based MXene, ($Ti_3C_2T_x$, where T = O, F, OH and so on) can be used as a highly selective detector of gases.

MXenes are a large family of 2-D transition metal carbides or nitrides, where representative MXenes such as $Ti_3C_2(OH)_2$ possess metallic conductivity, while the outer surface is fully covered with functional groups. Therefore, metallic conductivity and abundant surface functionalities may coexist without mutual interference. Such a combination makes them highly attractive for gas sensors with a high signal-to-noise ratio. This indicates the relative gas signal intensity over noise intensity, as the high coverage of functional groups allows strong binding with analytes, while the high metallic conductivity intrinsically leads to low noise.

According to the team, the signal-to-noise ratio of the $Ti_3C_2T_x$ sensors was up to two orders of magnitude higher compared with that of all other 2-D materials. Sensors used today have a signal-to-noise ratio of 3–10, while MXene's is between 170 and 350.

Although only one type of MXene was studied, it well exceeded the performance of conventional materials. The researchers expect that their study will open the door for a large family of Mxenes that could potentially be employed as highly sensitive sensors.

Mimicking cell behavior with functionalized surfactants

Active surfactants are those that are responsive to an external stimulus, such as temperature, light, electric or magnetic fields or chemical agents. Scientists from the Institute for Basic Science (Daejeon, South Korea; www.ibs.re.kr) have developed surfactants based on functionalized nanoparticle dimers that are responsive to magnetic, optical and electric fields simultaneously. These surfactants can be used to coat liquid droplets, which can then be manipulated by external stimuli and assembled into various hierarchical structures.

For example, the droplets can be manipulated with light absorbed by the nanoparticles. A laser causes the droplets to move toward the beam and form closely packed structures within seconds. The process is reversible and repeatable. Turning the laser on and off produces alternating assembly and scattering. When the light is guided to the edge of a droplet, it begins to rotate. If the droplet is located in a packed group, it can transfer mechanical torque to other droplets, thus acting like a system of mechanical gears. The speed and direction of rotation can be adjusted by the laser's angle and intensity.

While a magnetic and optical field manipulates the position and movement of a droplet, an electric field causes it to assume several shapes. Applying a strong electric pulse where two or more droplets touch causes the surfactant to swirl up and down simultaneously, creating permanent channels between the droplets or even merging them. Opening a channel between the droplets allows mixing their liquid contents.

Manipulating chemical reactions allows mimicking the behavior of cells, resulting in chemical plants on the nanoscale controlled by magnets and light. According to the scientists, their work opens up several more possibilities, such as light-guided 3-D printing, or coating living cells with nanosurfactants.

The new large-scale manufacturing line, built by Airborne at its facility in the Netherlands using Siemens factory automation and digital control software, can produce multiple thermoplastic composite laminates every minute, achieving over a million parts annually.

Machine-learning concepts will be used to fine-tune quality and adaptive process control will allow settings to be modified "on the fly." The new line will be supported by predictive engineering capabilities at SABIC's Center of Excellence in the Netherlands.

The new line will be able to mass-produce lightweight, high-modulus and low-warpage, custom-engineered laminates as per thickness, dimensions, lay-up preferences and desired performance. Made with carbon-fiber-reinforced polycarbonate composite, these SABIC laminates will be used for laptop covers.

NATURAL ROOM LIGHTING

A light guidance system that makes it possible to illuminate windowless rooms was introduced last month by

(Continues on p. 10)

BASF SE (Ludwigshafen, Germany; www.basf.com) and Bartenbach GmbH (Aldrans, Austria; www.bartenbach.com) at the Light + Building tradefair (Frankfurt, Germany; March 18–23). The system is based on three components: a film, a light shaft and light fixtures. The film is embedded in insulated glass, and guides light from outside to the light shaft, which contains a reflective film. The shaft brings sunlight into the interior of a building, where light fixtures shine the daylight into the rooms. Additional LED lamps are used when natural daylight is either unavailable or inefficient.

A prototype of the system is already being used in the Aldrans, Tyrol headquarters of Bartenbach in Austria.

POLAR BEAR HAIR

Inspired by the microstructure and thermal insulation properties of polar bear hair, researchers from the College of Chemical and Biological Engineering at Zhejiang University (Hangzhou, China; www.zju.edu.cn) have developed a synthetic fiber that can be woven into fabric with superior thermal insulation properties. The fiber is made by a freeze-spinning technique that continuously fabricates silk fibroin solution into a fiber with an aligned porous microstructure. In addition to the "remarkable thermal insulation," textile woven with the biomimetic fibers can be doped with carbon nanotubes for active electroheating capacity.

POWER-TO-GAS WITH HIGH EFFICIENCY

An efficiency of more than 75% has been achieved in a process that combines high-temperature (HT) electrolysis and methanation to convert electrical power into methane. Such substitute natural gas could serve as a buffer for weather-dependent electricity from the wind and sun, according to the Karlsruhe Institute of Technology (Germany; www.kit.edu). "For the first time, we used the synergies between electrolysis and methanation and reached an efficiency that exceeds that of standard technologies by about 20%," says professor Dimosthenis Trimis, head of the Chair of Combustion Technology at KIT, and coordinator of the of E.U. Helmeth project.

Reported last month, the 76% efficiency milestone was achieved in a prototype system that fits into two standard freight containers. Water is electrolyzed into H_2 and O_2 at high temperature (about 800°C) and pressure. The H_2 is then reacted with CO_2 or CO to form CH_4 in the methanation unit. The heat released from this exothermic reaction is used to supply the heating requirements of the HT electrolyzer. The product CH_4 contains less than 2 vol.% H_2, making it suitable for feeding the German natural gas network.

The four-year, €3.8 million Helmeth project was funded in part under the European Commission's 7th Framework Program for the Fuel Cells and Hydrogen Joint Technology Initiative. The project partners are KIT, the University of Turin, the Technical University of Athens, Sunfire GmbH and EthosEnergy Italia S.p.A., the European Research Institute of Catalysis (ERIC), and the German Technical and Scientific Assn. for Gas and Water (DVGW). ❑

Controlled polymerization makes high-performance polysiloxanes

Polysiloxanes are the main component of important industrial materials, such silicones and organosilicones. In recent years, demand has grown for higher-performance and higher-functionality of organosilicon materials, which require techniques that precisely control the structure of these materials. Although there are techniques capable of selectively forming one type of siloxane bond, such as the cross-condensation method, multistage synthesis has been necessary in order to obtain complex siloxane compounds.

Now, Keita Fuchise and colleagues at the Interdisciplinary Research Center for Catalytic Chemistry, National Institute of Advanced Industrial Science and Technology (IRC3, AIST, Tsukuba City, Japan; irc3.aist.go.jp) have developed a simple method for synthesizing polysiloxanes that have a well-controlled structure. With support from NEDO, the researchers developed a controlled, organo-catalytic living ring-opening polymerization of cyclotrisiloxanes. The reaction takes place at 30°C and uses water as an initiator and strong organic bases, such as amidinines, guanidines, phosphazene bases, and proazaphosphatrane, as catalysts. A variety of polysiloxanes can be produced with controlled number-average molecular weight (from 2.64 to 102.3 kg/mol), a narrow dispersity (D = 1.03–1.16) and well-defined structural symmetry.

The synthesis method is said to be very simple, and does not require a dewatering step due to the usage of water instead of lithium compounds as an initiator. By changing the ratio of cyclic trioxanes and water, the average molecular weight can be controlled to more than 100,000 (which corresponds to more than 1,350 Si–O units). The method can also be used for making block- and random-type copolymers. Structurally well-controlled polysiloxanes enables the development of silicone materials with higher performance and higher functionality, including longer life at high temperature, especially in the field of elastomers, gels, and surface-preparation and dispersing agents.

A panel reactor for splitting water into hydrogen

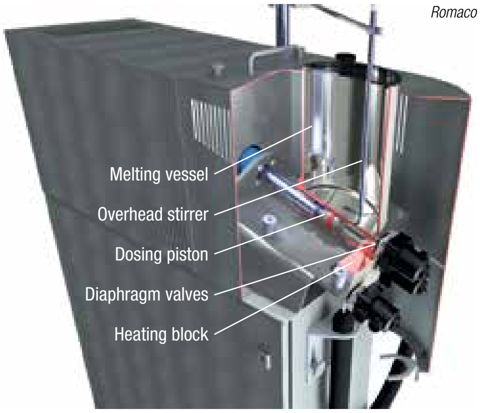
A group of Japanese researchers have developed a photocatalytic panel reactor with large area (1 m^2) that splits water into H_2 and O_2 using only natural sunlight. The NEDO-supported project — which includes partners Japan Technological Research Association of Artificial Photosynthetic Chemical Process (ARPChem; Tokyo), the University of Tokyo, Toto, Ltd. (Kanagawa), and Mitsubishi Chemical Corp. (Kanagawa) — aims to further the development of artificial photosynthesis for a future hydrogen-based economy.

The newly developed reactor contains sheets that are fabricated by coating a substrate with a photocatalyst — particles of Al-doped $SrTiO_3$. Water, with a depth of only 1 mm on the panel, is split into H_2 and O_2 upon exposure to natural sunlight, without the need for forced convection. With the 1-m^2 prototype, the researchers have demonstrated a solar-to-H_2 (STH) energy conversion of 0.4%, and an apparent quantum yield (AQY) of 56% at 365 nm. The evolution of gases could also be adjusted to a rate of 5.6 mL/cm^2/h, to give an apparent STH efficiency of 10%. The use of ceramic membranes is proposed as a way to separate the two gases, and to prevent the buildup of explosive mixtures of H_2 and O_2.

This shallow design, described in a recent issue of *Joule*, makes it possible to fabricate light reactors with inexpensive materials (such as plastic). Although alternative water-splitting methods, such as photoelectrochemical (PEC) or photovoltaic (PV) cells have achieved higher STH conversion efficiencies (as high as 30%), those designs are said to be difficult to scale up, due to long ion-transport distances required, as well as the need for large amounts of circulating electrolyte and buffer reagents. In contrast, the panel design operates with only water at a depth of 1 mm.

Hot-melt coating for pharma applications

Polymer coatings are often used to mask the taste of pharmaceuticals, as well as to serve as moisture barriers to granules or tablets. However, the application of polymer solutions requires considerable time and energy for drying after the coating has been applied. Processing times can now be shortened by up to 85% using a hot-melt coating technology developed by Romaco Innojet GmbH (Steinen, Germany; www.romanco.com).



Romaco

The company's IHD series was specially designed for coating and granulating pharmaceutical products with hot greases and waxes, which simply harden when cooled, thereby eliminating the time and energy needed for drying. Speaking at a pre-Achema press event at Dechema (Frankfurt am Main, Germany) last month, technology director Kai Koch presented an example of the coating of 1 kg of granulate. Whereas the conventional process of coating with a polymer solution 500 g polymer in 2,833 g of water requires 278 minutes of processing time to form the coated granulate, the hot-melt coating of 500 g onto the same granulate required only 42 minutes.

Although the technology has been used in other sectors, the company has now launched a system that is compliant with Good Manufacturing Practice (GMP), specifically for pharmaceutical applications. That means the device is clean-in-place (CIP) capable, particularly regarding the validation of the cleaning processes.

In the IHD device, the hot-melt coating flows through straight tubes to prevent any buildup of product residues. All product-contacted surfaces inside the devices are positioned in such a way that they are fully visible and suitable for swab testing. The IHD series successfully avoids cross-contamination thanks to the hygienic design with no dead spaces.

To allow precise and uniform heat distribution, the Innojet IHD was designed as a heatable monobloc integrating all functional components. The melting container, dosing unit and valve block are all included in the same thermal cycle, which means they do not have to be heated and insulated separately.

A laboratory device designed to handle 5 L was introduced last year, and a 50–L pilot-scale machine is being launched in April. ■

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Plant Watch

Evonik to construct new polyamide 12 plant at Marl Chemical Park

March 14, 2018 — Evonik Industries AG (Essen, Germany; www.evonik.com) is planning to build a new production complex for polyamide 12 (PA 12). The group intends to increase its overall PA 12 capacity by more than 50%. Evonik plans to invest approximately €400 million in the new PA 12 complex at its Marl Chemical Park in Germany. The new PA 12 plant is expected to start up in early 2021.

Chevron Phillips starts up ethane cracker in Baytown

March 13, 2018 — Chevron Phillips Chemical Co. LP (The Woodlands, Tex.; www.cpchem.com) has introduced feedstock and begun commercial operation of a new ethane cracker at its Cedar Bayou facility in Baytown, Tex. At peak production, the unit will produce 1.5 million metric tons per year (m.t./yr) of ethylene, which will be used at the company's derivatives units, including the two new polyethylene units at Old Ocean, Tex.

Airgas expands presence in California with new CO_2 plant, expanded ASU

March 7, 2018 — Airgas USA, LLC (Radnor, Pa.; www.airgas.com) plans to increase its presence in California with the construction of a new liquid-carbon-dioxide production facility in Stockton and the expansion of an air separation unit (ASU) in Etiwanda. Once onstream, the two facilities will significantly increase the company's capabilities in the state. The ASU expansion will be constructed within an existing ASU first inaugurated in 2011 by Air Liquide.

DuPont Tate & Lyle Bio Products to increase propanediol production capacity

March 7, 2018 — DuPont Tate & Lyle Bio Products, LLC, a joint venture (JV) between DuPont (Wilmington, Del.; www.dupont.com) and Tate & Lyle (London; www.tateandlyle.com), will expand its plant in Loudon, Tenn. to increase annual production of bio-based 1,3-propanediol by 35 million pounds. Engineering and construction is scheduled to start immediately and the expansion is expected to be completed by mid-2019.

BP licenses PTA process technology to Socar Turkey

February 28, 2018 — BP plc (London; www.bp.com) and Socar Turkey Enerji A.Ş. have entered into a licensing agreement for BP's latest-generation purified terephthalic acid (PTA) technology. Socar Turkey intends to deploy the technology in its new unit, which will have capacity to produce 900,000 m.t./yr of PTA, at Aliağa, Turkey, expected to come onstream by 2023.

Trinseo opens pilot plant and expanded S-SBR facility in Germany

February 28, 2018 — Trinseo (Berwyn, Pa.; www.trinseo.com) marked the opening of its new pilot plant and solution-styrene butadiene rubber (S-SBR) capacity expansion at Schkopau, Germany. The production expansion adds an additional 50,000 m.t./yr of S-SBR capacity to the Schkopau site and increases the company's global S-SBR production by 33%.

Lanxess expands capacity for Macrolex dyes at its Leverkusen site

February 22, 2018 — Lanxess AG (Cologne, Germany; www.lanxess.com) will expand the capacity for Macrolex dyes at its Leverkusen site. With an investment volume of more than €5 million, the current production capacity is to be increased by 25%, which will be available beginning in late 2018.

Westlake to expand PVC and VCM production in Germany and the U.S.

February 20, 2018 — Westlake Chemical Corp. (Houston; www.westlake.com) will expand production capacities for polyvinyl chloride (PVC) and vinyl chloride monomer (VCM) at three of its chemical facilities. Two of the plants are located in Germany (Burghausen and Gendorf) and one is located in Geismar, Louisiana. The expansions in Burghausen and Geismar are expected to be completed in 2019. The Gendorf expansions are expected to be completed in 2020 and 2021.

Stamicarbon signs contract to license a urea plant in Brunei

February 20, 2018 — Stamicarbon B.V. (Sittard, the Netherlands; www.stamicarbon.com) has signed a license agreement for the construction of a greenfield urea-melt plant owned by Brunei Fertilizer Industries, which will be located at Sungai Liang Industrial Park in Brunei. The urea plant will have a capacity of 3,900 m.t./d.

Mergers & Acquisitions

Huntsman acquires spray polyurethane foam manufacturer Demilec

March 14, 2018 — Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com) has acquired Demilec, a manufacturer of spray polyurethane foam (SPF) insulation systems. Demilec has two manufacturing facilities located in Arlington, Tex. and Boisbriand, Quebec, Canada. Under the terms of the agreement, Huntsman will pay $350 million in an all-cash transaction, which is expected to close by the end the second quarter of 2018.

Kuraray, PTTGC and Sumitomo to establish butadiene JV in Thailand

March 9, 2018 — Kuraray Co., Ltd. (Tokyo, Japan; www.kuraray.com), PTT Global Chemical (PTTGC; Bangkok, Thailand; www.pttgcgroup.com) and Sumitomo Corp. (Tokyo; www.sumitomocorp.co.jp) have signed an agreement to establish a JV company focused on producing butadiene derivatives in Thailand. Kuraray will hold 53.3% of the joint company, PTTGC will hold 33.4% and Sumitomo will own 13.3%.

Solenis acquires Belgian coatings company Topchim

March 7, 2018 — Solenis International, L.P. (Wilmington, Del.; www.solenis.com) completed the acquisition of 100% of the shares of Topchim N.V. (Antwerp, Belgium). Topchim provides ecological coatings for the European paper, cardboard and packaging converting industries.

Ecolab sells Chinese phosphonate business to Italmatch

March 7, 2018 — Ecolab Inc. (St. Paul, Minn.; www.ecolab.com) has sold its phosphonate-component business in China, Jaiyou Chemical Co., which was acquired as part of its 2015 Jianghai acquisition, to Italmatch Chemicals S.p.A. (Genova, Italy; www.italmatch.com). The deal includes the acquisition of the entire antiscalant business and assets relating to phosphonate production and sales.

Mitsubishi Chemical and Linde Engineering enter technology transfer

March 1, 2018 — The Engineering Division of The Linde Group (Munich, Germany; www.linde-engineering.com) and Mitsubishi Chemical Corp. (MCC; Tokyo; www.m-chemical.co.jp) have concluded an agreement for the transfer of MCC's hydrodealkylation (HDA) technology to Linde. The HDA technology mainly converts toluene and other aromatic components into high-purity benzene. The technology transfer to Linde is expected to be completed by June 2018.

Norsk Hydro acquires aluminum assets in Iceland, Sweden and the Netherlands

February 27, 2018 — Norsk Hydro ASA (Oslo, Norway; www.hydro.com) has offered to acquire Rio Tinto's 100% share in Icelandic aluminum plant ISAL. ISAL produces 210,000 m.t./yr of liquid metal and 230,000 m.t./yr of extrusion ingot. With the transaction, Norsk Hydro will also acquire Rio Tinto's 53% share in Dutch anode facility Aluminum & Chemie Rotterdam B.V. and 50% of the shares in Swedish aluminum fluoride plant Alufluor AB for $345 million.

LyondellBasell to acquire A. Schulman for $2.25 billion

February 16, 2018 — LyondellBasell (Rotterdam, the Netherlands; www.lyondellbasell.com) and A. Schulman, Inc. (Akron, Ohio; www.aschulman.com) have entered into a definitive agreement under which LyondellBasell will acquire A. Schulman for a total consideration of $2.25 billion. The acquisition is expected to close in the second half of 2018. ■

Mary Page Bailey

Lithium Battery Demand Drives Process Evolution

An explosion in battery demand has fostered a welcoming environment for innovations in sourcing and processing lithium and cobalt

IN BRIEF

The drive for higher capacity and ehanced performance from lithium-ion batteries (LIBs), in conjunction with skyrocketing demand for electronic devices and electric vehicles (EVs), has necessitated innovations in sourcing, processing and recycling the major materials used in battery manufacturing, especially lithium and cobalt.

Processes and equipment evolve

One side effect of the increasing demand for lithium is a rush-to-market tendency from mining companies. "Over the next several years, a number of companies are coming online to extract lithium carbonate from spodumene ore, which is typically about 8% Li_2O by weight. In order to meet demand, it's been a rush to start up," says Josh Marion, a project engineer from Jenike & Johanson Inc. (Tyngsboro, Mass.; www.jenike.com). This rush, combined with the high value of lithium and its specific physical properties, underlines the importance of proper design throughout all stages of lithium processing — from initial mining all the way to the final refining steps. This forces processors to approach bulk solids handling in a new way when trying to achieve the desired benchmarks for product purity, particle size and density. "A lot of the processing demands can be likened more to pharmaceutical manufacturing than traditional mineral processing. There's a premium on the quality of material that goes to battery manufacturers, and without reliable solids handling, you cannot achieve the product uniformity that is required," explains Marion.

Some of the main operational issues experienced by lithium processors include caking, buildup and flow stoppage. To extract lithium from spodumene ore after mining, the raw ore goes through a series of crushing and size-classification steps to generate ore of the required particle size. The fine ore is then sent to a concentrator plant where it goes through several drying, milling, separation, dewatering

GEA

FIGURE 1. New nozzles developed specifically for spray-drying processes that handle lithium help to achieve the narrow particle-size range required for battery-grade products

and further size-classification steps to generate spodumene concentrate. The concentrate then proceeds to a processing plant, where it is calcined, and various aqueous solutions, acids and other chemicals are added to extract different impurities, such as iron, aluminum, silicon and magnesium. Finally, the wet cake is recrystallized and dried into the lithium hydroxide (LiOH) or lithium carbonate (Li_2CO_3) product. "Particularly during those steps where the lithium is in a wet cake, if you don't have an adequate dryer or the handling equipment is not properly designed to handle slightly wet material, you often experience buildup of lithium and lithium cake throughout the plant. Also, due to the hygroscopic nature of lithium salts, even when the material is dry, it may tend to absorb moisture and cake," says Marion. He emphasizes that attention to detail during the equipment design phase is crucial in avoiding these bottlenecks and ensuring consistent product quality. "When selecting and designing equipment, it is critical to ensure that the characteristics of the material at each stage of the process be considered," he adds.

As the performance demands of LIBs have

American Manganese

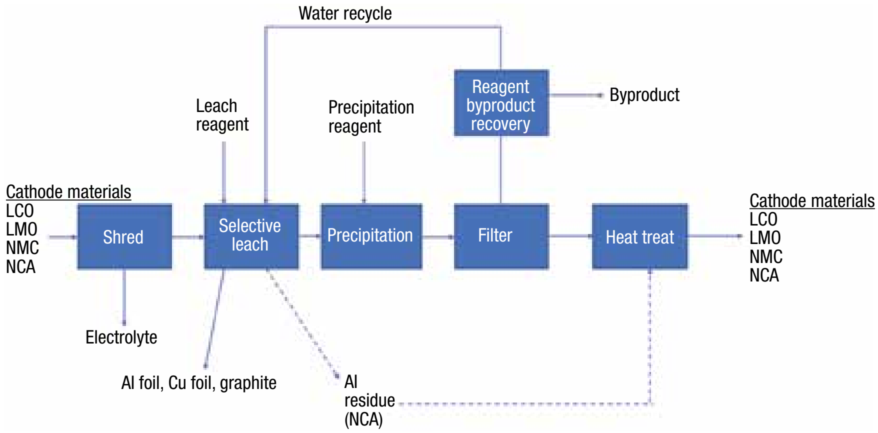


FIGURE 2. A manganese-recovery technology for low-grade ores has been adapted to recycle metals from spent battery cathodes

evolved, equipment manufacturers are developing new technologies to meet those needs. "The key parameters for lithium producers right now are purity and particle size," says Ananta Islam, sales director for the North American chemicals division of GEA Group AG (Düsseldorf, Germany; www.gea.com). The presence of certain impurities directly impacts battery performance, so lithium producers must align with a strict set of purity specifications. "Users are looking for a very low concentration of sodium, potassium, sulfur and heavy metals inside a battery-grade product," explains Christian Melches, senior sales and technology manager at GEA. Whether starting with brine materials, as is common in South America, or spodumene ore, the typical lithium source in Canada and Australia, these impurities are typically present in considerable amounts. To address purity concerns, GEA provides crystallization units that can be combined to optimize purification, says Melches. "The edge comes from knowing how to guide the flows through the process itself to several crystallizers to get the purest product," he states. Another important consideration in combined crystallization units is energy efficiency. One energy-saving measure is the use of mechanical recompression of vapors from the crystallizer to create steam for driving the process.

LiOH — currently the preferred lithium form for most LIB makers — demands an extremely precise particle-size distribution, which requires specialized spray-drying equipment. A typical particle-size range for conventional spray drying might be 40–50 µm, but for LiOH processing, the range is around 5–7 µm, explains Islam. To ensure that materials meet requirements, GEA developed and patented a specific nozzle for lithium handling (Figure 1). "The Combi-Nozzle utilizes a high-pressure nozzle and compressed air for secondary atomization to further reduce the particle size," says Islam. Lithium producers say that a smaller particle size is needed for properly compacting powders, which directly affects LIB performance. According to Islam, this particular nozzle was developed based on technologies used in the pharmaceutical sector for spray drying particles for inhalable drugs, which require very fine particle sizes.

While brine and spodumene produce the majority of today's lithium, in the next few years, other sources may arise due to high demand. "The mining companies are starting to invest in alternative lithium sources, so in the future, processing equipment may need to adjust to handle more impure raw materials," says Melches.

TABLE 1. COMMON LIB CHEMISTRIES	
Lithium cobalt oxide ($LiCoO_2$)	LCO
Lithium manganese oxide ($LiMn_2O_4$)	LMO
Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$)	NMC
Lithium nickel cobalt aluminum oxide ($LiNiCoAlO_2$)	NCA
Lithium titanate ($Li_4Ti_5O_{12}$)	LTO
Lithium iron phosphate ($LiFePO_4$)	LFP

Looking to additional Li sources

In attempts to expand resource utilization and drive down LIB costs, technologies are emerging that introduce more feedstock flexibility for different lithium formulations and lower-grade raw materials. Nano One Materials Corp. (Vancouver, B.C., Canada; www.nanoone.ca) has developed a proprietary process for making battery cathode materials of various chemistries. Table 1 lists the most common LIB chemistries on the market. Unlike typical solid-state cathode production techniques, Nano One's technology is solution-based. "The solution-based process allows us to make battery materials more cheaply, and the process is very flexible, so it can be used to make any of the many formulations of lithium cathode materials," says Stephen Campbell, principal scientist at Nano One Materials. As battery makers try to optimize LIB capacity, stability and costs, great effort has gone into reducing the cobalt content while increasing the nickel content in cathodes. For making these high-nickel materials, LiOH is the preferred lithium raw material, but it is becoming more and more difficult and expensive to obtain. Nano One's technology can use either LiOH or the much more abundant and inexpensive Li_2CO_3 to make cathode materials, offering a more straightforward path for Li_2CO_3 producers, allowing them to avoid investing in costly processes to convert Li_2CO_3 to LiOH. "We can loosen up the supply chain by using lithium sources that others can't," says Campbell.

Nano One's solution-based technology dissolves the lithium in water (at ambient conditions) with other transition metals, so it doesn't matter what form the lithium is in — both LiOH and Li_2CO_3 are treated in the same manner. The dissolved metals are precipitated out, producing a crystalline precursor with an ordered lattice structure of all present cathode metals. This ordered structure facilitates faster firing in the furnace, says Campbell. "We can fire the materials in as little as 7 h, because the metals are already mixed in an ordered fashion. Traditional methods that grind lithium with other metals require long-distance diffusion, which can take 1 to 2 days of firing," he adds. Another benefit of Nano One's technology is that the

crystal uniformity dilutes impurities, making the process more tolerant of lower-grade raw materials, further driving down operating costs. Nano One is currently conducting tests on lithium samples with varying degrees of purity to evaluate the technology's ability to handle various contaminant species. "We are seeing that the impact of certain impurities is not as bad as some might think. For instance, magnesium can act as a dopant and actually improve performance," explains Campbell. Nano One is currently capable of producing cathode materials in 300-kg batches at a pilot plant, and the plant has capabilities to produce up to 1 ton/d. The team recently began sending product samples to third-party organizations for validation.

Battery recycling

Spent and scrapped batteries hold a staggering amount of highly in-demand materials, and many organizations are working to develop efficient recycling technologies to take advantage of this largely untapped resource. American Manganese Inc. (AMY; Surrey, B.C., Canada; www.americanmanganeseinc.com) has developed a process for recycling the cathode metals (including lithium, cobalt, manganese, nickel and aluminum) from EV batteries (Figure 2). The company is currently constructing a kilogram-scale pilot plant to demonstrate the technology, which is adapted from a proven continuous process for recovering manganese from low-grade ores, says Larry Reaugh, AMY president and chief executive officer (CEO). A commercial plant with a capacity of 3 m.t./d is in the works, which will utilize scraps or off-spec metals from LIB producers. In bench-scale tests, 100% of cathode metals were recovered from LIB materials and scrap, which typically would end up in a landfill or in a smelter with inefficient metal recovery that may not even recover any of the cathode's lithium. The AMY process should readily scale up, due to its history of proven continuous operation at larger production levels with manganese, explains Reaugh.

Using sulfur dioxide and other low-cost reagents and an automated battery-disassembly process, AMY's recycling technology produces little to no waste, as 100% of metals are recovered and process water is recirculated. The revolutionary part of the hydrometallurgical process, says Reaugh, simplifies the precipitation step and increases metal yields, and has flexibility to work with many metals and cathode chemistries.

Looking at the future supply and demand for battery materials like lithium and cobalt, Reaugh believes the benefits are clear when comparing recycling processes with mining. "The price of cobalt is going through the roof and there doesn't seem to be any immediate production coming onstream, and with new mines, you are looking at years and years of lead time," he adds. "I think our economics with recycling will be hands-down better than mining."

Another new technique for recycling cathode materials from spent LIBs has been developed by engineers at the University of California (UC) San Diego (www.ucsd.edu). The process begins with a non-destructive particle-separation step that involves binder dissolution, suspension, filtration and washing, followed by hydrothermal lithiation

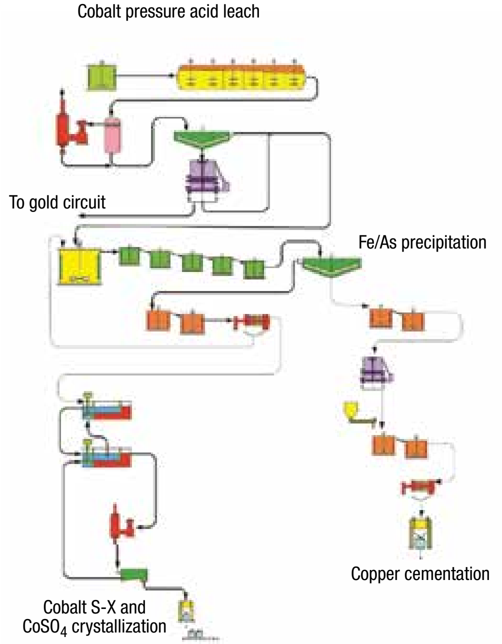


FIGURE 3. Fortune Minerals' metal refining plant will process cobalt, bismuth, gold and copper

treatment where cathode particles are pressurized in an alkaline solution in the presence of lithium salt. A subsequent annealing step helps to correct the crystal structure of the materials, which might have degraded during previous battery use, explains Zheng Chen, professor of nanoengineering at UC San Diego. According to the research team, battery materials recovered in this process were restored to their original performance capabilities with regard to charge storage capacity, charging time and battery lifetime.

A major benefit of this process is its energy efficiency when compared to other battery-recycling techniques, says Chen. "We do not destruct the majority of the particle structure and composition, which consumes a great deal of energy to re-create. Avoiding repeating these manufacturing steps helps to save energy," he states. The process has been demonstrated at the gram scale and has been proven to work for both LCO and NMC batteries, making it flexible to handle LIBs from EVs and consumer electronics.

Metals from fossil fuel processing

The intensifying global demand for LIBs has forced the industry to consider alternative sources for many metals, and in several cases, look to traditional oil-and-gas processes for inspiration. A new technology developed by MGX Minerals Inc. (www.mgxminerals.com) in partnership with Highbury Energy Inc. (both Vancouver; www.highburyenergy.com) seeks to recover metals used in LIBs from a major byproduct of petroleum refining — petroleum coke (petcoke). The petcoke is fed to an advanced thermochemical gasification process to produce hydrogen and an ash byproduct, from which high-value metals are recovered, including nickel and cobalt, as well as a wide variety of rare-earth elements in smaller concentrations. High demand for hydrogen combined with the massive amount of inexpensive petcoke feedstock make this project appealing. The key to its effectiveness for metals recovery lies in the precision of the gasification fluid-bed reactor technology to eliminate the tar and residue buildup that can typically plague gasification operations. "The process requires low-tar gasification and a clean ash byproduct. The last thing we want is tar or organic materials in the ash itself, which would make processing of the metals quite difficult," explains Jared Lazerson, president and CEO of MGX Minerals. Another benefit of this gasification process is its ability to handle a very large range of particle sizes, including very fine materials. The metals recovery step is relatively straightforward since the gasification unit acts as a concentrator.

The ability to co-locate the petcoke gasification and metals-recovery processes alongside oil-sands processing sites eliminates logistics and transportation concerns, according to Lazerson. Highbury Energy has operated a gasification pilot plant for several years using its proprietary fluid-bed-reactor technology. "We are just beginning to figure out what the next phases are in terms of whether to move into a pilot or small commercial plant," says Lazerson.

On the lithium side, MGX Minerals is progressing its nanofiltration technology for lithium recovery. In this process, a patented high-intensity flotation process uses micro-bubbles to clean out residual oils, metals and small particulate matter from feedstock — typically brine, mine tailings or lithium-containing wastewater from oil-and-gas or chemical processing sites. This step removes 99% of physical particulates, says Lazerson, providing a very clean brine source for the nanofiltration step, which then further refines the lithium stream to the purity levels required for LIB manufacturing. "Basically, it's an adsorption technology in highly specialized nanofilters," he adds. "We remove impurities like sodium, magnesium and calcium in step one, so you end up with a very clean lithium concentrate, along with other salt concentrates that can be monetized," Lazerson mentions. The company is close to completing its first commercial plant and is evaluating where to install its next plant. The current production scale at the plant is 750 bbl/d, and initial construction work is underway for a 7,500-bbl/day system. MGX Minerals is also working with partners in South and North America, including potential deployment at a large-scale natural-brine site related to geothermal processing in Southern California. The company also recently announced a joint development project with Orion Laboratories LLC and Light Metals International Inc. to commercialize a new modular thermochemical process to produce high-purity Li_2CO_3 or LiOH from spodumene concentrates.

Another potential source of lithium is wastewater generated from hydraulic fracturing activities. A group from the University of Texas at Austin (UT; www.utexas.edu), in collaboration with Monash University (Melbourne, Australia, www.monash.edu) and CSIRO (Melbourne, Australia; www.csiro.au), has developed a membrane process using metal-organic frameworks (MOFs) that can selectively extract lithium from wastewater. "The particular MOFs considered for this work have pore sizes that can accommodate a partially dehydrated lithium ion, but not larger ions or highly hydrated ions, making it selective for lithium, relative to larger partially dehydrated ions, such as sodium, potassium and rubidium," explains Benny Freeman, a chemical engineering

professor at UT. "Our current hypothesis is that the lithium ions partially dehydrate to enter the MOF pore, where they undergo extremely rapid transport through the nanocrystalline voids inside the MOF crystals. This mechanism implies favorable interactions of the MOF interiors with lithium ions, bringing about at least partial dehydration of the ions," Freeman adds. Currently, the MOF membranes have been demonstrated at the laboratory scale, but the group from UT is working to adapt the technology for CSIRO's established continuous-flow process to produce larger quantities of MOFs. The team believes that this technology is not restricted to lithium, and the MOF could be used for desalination purposes, or tuned to selectively permeate monovalent anions, for instance removing fluoride from drinking water or nitrates from agricultural runoff.

Sourcing cobalt closer to home

Increases in LIB manufacturing capacity have placed unique stresses on the supply of cobalt. Not only is cobalt mined in politically unstable regions, but it is primarily recovered as a byproduct of nickel and copper mining, so its economics are tied up in the demands of those markets. Recognizing the necessity for new primary sources of cobalt to satisfy demands, Fortune Minerals Ltd. (London, Ont., Canada; www.fortuneminerals.com) is embarking on an extensive cobalt project in North America, a region with very little dedicated cobalt production. Fortune Minerals' project comprises mining of cobalt, gold, bismuth and copper at a large deposit in Canada's Northwest Territories and a hydrometallurgical refining plant in Saskatchewan that will process metal concentrates from the mine. "This project basically mitigates supply-chain risks by having a North American vertically integrated source with supply-chain transparency," explains Robin Goad, president and CEO of Fortune Minerals. The project has undergone feasibility and front-end engineering design (FEED) studies, and the group is currently completing a new feasibility study to consider a 30% increase in production rate. "We are targeting production of approximately 2,000 tons of cobalt per year contained in cobalt sulfate heptahydrate, which is the preferred material for NCA and NMC batteries used in the automotive industry," says Goad.

The Saskatchewan plant will process metal concentrates from the mine, beginning with bismuth. In the bismuth processing unit, a secondary flotation step yields a gold-bearing cobalt sulfide concentrate, which is subsequently fed to the cobalt processing unit (Figure 3). Here, the cobalt concentrate is subjected to high-pressure acid leaching at 180°C in an autoclave. "The cobalt sulfide dissolves into solution in an exothermic reaction. There is little acid consumption because the sulfide minerals generate acid during their dissolution," explains Goad. Next, gold is recovered and sent to a separate process unit, the cobalt materials are neutralized and impurities — iron, copper, and most crucially, arsenic — are precipitated out, resulting in a relatively pure cobalt stream. "We strip off the arsenic impurity and convert it to ferric arsenate using the excess iron in solution. The arsenic, which would otherwise be toxic, is now in a non-hazardous stable form that can be safely landfilled at the project site," Goad adds. This arsenic conversion step is especially critical in enabling the plant to process metals from other mines, as much new cobalt production is arsenic-based, and there are limitations in exporting arsenic-containing compounds. "In addition to processing concentrates from our own mine, we think the refining plant will be very well positioned to process concentrates from other cobalt projects around North America," says Goad. Fortune Minerals expects construction of the plant to begin in early 2019. Commissioning and commercial operation would follow in 2021. "The longterm business plan is to diversify into recycling, because we will have a plant that will be able to take residues, metal shavings or waste batteries and recover the metals," mentions Goad. He emphasizes that an infrastructure supporting collection points for these waste streams will need to be established before large-scale recycling can take place. ■

Mary Page Bailey

Level Measurement: One Size Does Not Fit All

Today's level measurement instruments are smarter, easier to use and designed to meet the challenges of the CPI

IN BRIEF

- DIFFICULT PROCESS CONDITIONS
- AGGRESSIVE MEDIA
- VESSEL SIZE AND OBSTRUCTIONS
- STEAM GENERATION
- WET SOLIDS
- SAFETY REQUIREMENTS
- INTELLIGENT INSTRUMENTATION

When it comes to level measurement, chemical processors long for a "silver bullet" technology that works in every application. Unfortunately, there isn't one. On the bright side, there are many types of level measurement devices available, so one is sure to work in any given application, no matter how demanding. And that's a good thing because in the chemical process industries (CPI), the applications tend to be both challenging and critical due to the process extremes and the materials being measured. For this reason, whatever technology is chosen, it must be both reliable in application and ensure safety, which means that today's level measurement instruments are smarter, easier to use and designed to meet these requirements.

FIGURE 1. Endress+Hauser's Micropilot FRM62 was designed for 80-GHz level measurement in aggressive liquids. The radar technology offers a completely PTFE-filled and flush-mounted antenna

"Our customers want one technology that will fit all their needs and all their applications," says Gene Henry, product marketing manager for level with Endress+Hauser (E+H; Greenwood, Ind.; www.us.endress.com). "Finding a 'silver bullet' technology is especially difficult in the chemical processing industries because they have higher pressures and higher temperatures, a lot of applications that are corrosive and a host of other issues, such as condensation, foam or obstructions. When you combine these characteristics and the effects they can have on instrumentation and equipment, it becomes obvious that trying to shoehorn one specific technology into all applications can't be done."

Selecting the right instrument for the right application can be a challenge in its own right. "Doing level correctly is an art form," says Henry. "A device may be designed for one type of application, so it isn't always possible to offer that same device elsewhere and know it's going to work, but finding the right device is possible."

To do so, processors must consider process environment factors, such as temperature and pressure, as well as conditions such as aggressive media, turbulence and condensation. Knowing the history of level measurement devices that have worked, or not, in the past is also helpful. "Often the questions come up when something isn't working with a certain type of level instrument and we have to find the next best solution," notes Dean Mallon, national marketing manager for level with E+H. "That's when equipment experts have to start looking in-depth at the real parameters: the pressure, temperature, density of product, the history, how the current device has been working and what is going on that presents the opportunity to offer something else. We have to uncover the challenges and, based upon experience and knowledge, make recommendations of what might work better and then make sure the instrument is installed and configured correctly so that the new technology is bringing the reliability they expect and need."

Difficult process conditions

Most of the difficult process conditions are related to the environment within the process, says Mike Bequette, vice president of engineering with SOR Measurement and Control (Lenexa, Kan.; www.sorinc.com). "Because every chemical and every process is different, there can be a variety of issues that present technology challenges. You can have reflections, vapor pressure, condensation, foam, agitation or turbulence in a tank,

corrosive materials and the list goes on. Each of these issues can impact or affect the ability of an instrument to function reliably in any given application. For example, condensation can affect the accuracy of radar technologies or a changing specific gravity can affect accuracy of a pressure transmitter used to measure level. That's why is it important to look at these conditions to find the right instrument for the application."

Aggressive media. One of the biggest considerations when selecting instruments for use in the CPI is aggressive media. "In chemical processing, the materials are often toxic, aggressive and corrosive, so finding the correct instrument for those applications is important because these types of materials can affect the accuracy, reliability and safety of the instruments," explains Herman Coello, product marketing manager for level with Siemens (Alpharetta, Ga.; www.usa.siemens.com).

Siemens introduced its Sitrans LR250 radar level transmitters with a flanged encapsulated antenna (FEA) for continuous monitoring of liquids and slurries in storage and process vessels, including corrosive or aggressive materials. The two-wire, 25-GHz pulse-radar level transmitter features a lens that is compatible with most materials and is the only part of the instrument that comes in contact with the media, says Coello. "In the past when there was a situation that involved aggressive media, we needed expensive alloys, but this flanged encapsulated antenna means corrosive or aggressive materials are no longer a challenge."

Similarly, E+H's Micropilot FRM62 (Figure 1) was designed for 80 GHz level measurement in aggressive liquids. The radar technology offers a completely PTFE-filled (polytetrafluoroethylene) and flush-mounted antenna. The integrated PEEK (polyether ether ketone) antenna allows very small process connections and the free space radar provides reliability due to improved algorithms and small beam angle.

Emerson

FIGURE 2. The Rosemount 5408 non-contacting radar level transmitter uses two-wire FMCW technology and deploys a continuous echo to maximize radar signal strength and produce a reliable measurement in demanding applications

Another benefit of this technology is that it provides an advantage in the chemical industry where many of the vessels are tall and narrow with a lot of obstructions, notes E+H's Mallon. "The small beam angle of the instrument and our Multi-Echo Track-

Hawk Measurement

FIGURE 3. Acoustic wave technology, such as the Gladiator Acoustic Switch from Hawk Measurement, provides better performance in tough solids applications with heavy, wet buildup and moisture in the environment

Ametek Drexelbrook

FIGURE 4. The Drexelbrook Safety IntelliPoint RF represents a significant advance in RF admittance reliability that addresses applications requiring safety instrumented functionality

ing evaluation provide the ability to measure reliably in these types of vessels, even in aggressive liquids," notes Mallon.

Vessel size and obstructions. Ingemar Serneby, senior applications specialist for measurement and analytical with Emerson's Rosemount Level Center of Excellence (Gothenberg, Sweden; www.emerson.com), agrees that the vessels used in chemical processing can also pose a challenge. "They can be quite small in size and contain heating coils, agitators and baffles, which reduce the surface tension and cause turbulence, foam and other factors that can be challenging," he says. "For these situations, we recommend non-contacting radar with frequency modulated continuous wave (FMCW) technology," he says. "FMCW is more sensitive than previous technologies so it allows measurement despite things like obstructions, turbulence and foam."

Emerson offers its Rosemount 5408 non-contacting radar level transmitter (Figure 2) for both liquid and solid materials measurement. Using two-wire FMCW technology, the instrument deploys a continuous echo to maximize radar signal

strength and produce a reliable measurement in demanding applications.

When it comes to small tanks, perhaps no other vessels are more challenged than those used in R&D applications, which employ scaled-down versions of larger process equipment, but still face the same process challenges, such as pressures, temperatures, corrosive media and other process issues, including foam and condensation, says Steve Sawyer, technical sales manager with Dynatrol (Houston; www.dynatrolusa.com).

"Imagine a scaled-down version of a hydrocarbon cracking application," he explains. "Rather than a 100-ft cracker, you've got a 3-ft vessel with high temperatures and high pressures, so you need a reliable level measurement device that will work within these scaled-down parameters," he says. His company offers the Dynatrol CL-10H liquid level switch, which has no packing gland, diaphragm, float, bearing, bellows or pressure seal in its design. The device provides rugged construction with a sensitive transmission of vibration energy through a rigid, all-welded pressure seal. "It's a unique device in that it works on a vibration principle, which provides an accurate level measurement within a high-pressure, high-temperature vessel and provides an output signal that can feed into the program that is controlling the other functions of the process," says Sawyer.

Steam generation. Another common challenge in chemical and petrochemical processes, says Emerson's Serneby, is that they sometimes generate a lot of steam, which can also affect level measurement. "It is difficult to handle steam with traditional devices," he says. "So for our guided-wave radar, we have developed dynamic vapor compensation technology that measures a reference and compensates for the propagation of the wave in the vapor space." The Rosemount 5300 Series guided-wave radar transmitters with this option eliminate accuracy errors associated with varying pressure and/or temperature that occur in vessels involving steam vapor. The dynamic vapor compensation option includes a probe with a built-in reflector and software, offers safety with a gastight dual seal, is corrosion-resistant and has no moving parts. It uses a reference reflector at fixed distance on a rigid single probe to measure vapor dielectric.

Wet solids. Another tough application involves the measurement of solid materials where moisture may be present, says Jack Evans, president of Hawk Measurement (Lawrence, Mass.; www.hawkmeasure.com). "When it comes to the measurement of solids, it must be emphasized that there are industries that have dry solids, and then applications that have moisture," he says. "And in these level measurement applications, things must be kept clean so that performance can continue, so there either has to be lots of periodic maintenance to keep the sensing elements clear of coating or the technology must have that feature built in. Hereto the technology of acoustic wave, which has the built-in capability to keep the propagating sensor surface free of coating or buildup, regardless of the material being wet or dry" (Figure 3).

SOR

FIGURE 5. SOR's 815 DT smart differential pressure transmitter can be used for level, differential pressure or flow measurement in hazardous locations and hostile environments, and is available with a low-power option that allows it to operate with wireless systems

While acoustic wave has sometimes been considered to be the same as ultrasonic technology, Evans suggests that acoustic wave provides better performance in tough solids applications with heavy, wet buildup and moisture in the environment. He says the technology is not affected by the coating or buildup because its low frequency and high power create strong frequent pressure-wave activity on the transducer face, which keeps the material off. This pulsing power on the transducer provides the self-cleaning feature that provides the better performance under these demanding conditions.

Safety requirements

While not a process challenge, per se, more chemical processors are demanding safety certified level instruments due to the hazardous nature of the materials and the criticality of the processes. "We are seeing more significant trends toward increased regulatory control and more awareness of safety in the industry, along with a need for greater reliability in spill prevention and overfill protection applications," says Bob Irving, director of marketing and business development with Ametek Drexelbrook (Horsham, Pa.; www.drexelbrook.com). "So our focus has been on adding safety certifications and developing instruments that help eliminate any possibility of a spill condition."

As such, the company expanded its point level offering with a fully certified SIL 2 (safety integrity level 2) safety point level switch that provides highly reliable overfill protection, specifically for applications in which there is a high cost of failure. The Drexelbrook Safety IntelliPoint RF represents a significant advance in RF admittance reliability that addresses applications requiring safety instrumented functionality (Figure 4). The SIL IntelliPoint offers a full line of measurement probes to fit any process application where safety overfill protection is required. The premium point level switch was designed to perform in challenging operating environments with extreme reliability while meeting API 2350 overfill protection standards. Its features and functions also make it suitable for use in safety-related systems with requirements for functional safety for SIL 2 (SIL 3 with redundant switch). It is certified in accordance with IEC61508-2 and has worldwide hazardous area approvals.

Intelligent instrumentation

Because level measurement is often used in critical applications, chemical processors began requesting smarter instruments that could alert them when there was a problem, so many equipment providers have added diagnostic functionality to their level-measurement devices.

"We've spent a lot of time adding intelligence to our instruments in an effort to help customers know when something is happening with the instruments before it leads to failure of the instrument," says E+H's Henry. E+H's Mallon continues, "We call it HeartBeat technology, and it can monitor how the instrument performs today compared to how it performed when it was new. The instrument can take those values, monitor the quality of the signal and transmit the data so that the users can use it to do predictive maintenance and respond to issues before failure happens, before they lose quality of the product, before they have a spill or before they have a safety issue."

In addition to diagnostic abilities that improve reliability, the built-in intelligence gives processors information they can use to improve the process throughput and efficiency, says SOR's Bequette. "If the device can provide information on level, temperature and other parameters across the vessel, it provides the end user with more data to make better decisions about how to run the process or the reaction to get better throughput."

In an effort to provide more information on the instrument and process, SOR introduced its 815 DT smart differential pressure transmitter (Figure 5), which can be used for level, differential pressure or flow measurement in hazardous locations and hostile environments, and is available with a low-power option that allows it to operate with wireless systems. "It is a highly advanced instrument that provides all the necessary information on several parameters, as well as level and volume out of tank, and can measure and produce a discreet output for control of things like turning on a pump or opening a valve."

While there appears to be a dizzying array of level technologies available with different advantages, features and levels of intelligence, every technology does have its place somewhere in the process industry. "Whether it is liquid or solid material, the selection of the technology must be reviewed carefully and all applications of dust, condensation, surface conditions, temperature and pressure and many more have to be considered," explains Hawk's Evans. "One technology should not be considered the universal solution to all level measurement applications, as there are likely other technologies that will fit more appropriately in an application." ■

Joy LePree

Pumps

KSB

Watson-Marlow Fluid Technology Group

Alfa Laval

Netzsch Pumps & Systems

Compact high-pressure pump for plant engineering

This company extended its product range of compact high-pressure Movitec pumps with a new horizontal version (photo), the H(S)I. Rather than being arranged in line as is common for this type of pump, the suction nozzle and discharge nozzle are arranged at a 90-deg angle, which is typical for process centrifugal pumps. The pumps are suitable for applications such as water distribution, water treatment, cooling water supply, boiler feed and pressure boosting. All wetted parts are made of high-grade stainless steel. The new pumps deliver a maximum flowrate of 26 m^3/h and a maximum discharge head of 195 m. — *KSB SE & Co. KGaA, Frankenthal, Germany*
www.ksb.com

A metering pump optimized for NaClO applications

The new Qdos 20 pump (photo) has been developed to offer highly accurate sodium hypochlorite metering in disinfection applications with flowrates up to 32 gal/h at a maximum of 100 psi pressure. It is especially suitable for applications at the well sites of many smaller water treatment plants, where operators are often injecting into water lines at higher pressure. The new model is designed as a drop-in replacement for diaphragm pumps. Its intuitive interface provides simple control of the pump via manual, 4–20-mA, contact or Profibus control. The brushless, d.c.-motor control maintains flow accuracy of ±1% with a repeatability of ±0.5% and a turndown ratio of 3,330:1. — *Watson-Marlow Fluid Technology Group, Falmouth, Cornwall, U.K.*
www.watson-marlow.com

A pump for ultrapure applications

UltraPure pumps (photo) are specifically designed for pharmaceutical applications, which involve high-value, high-risk productions, and deliver reliability and repeatability in process-driven productions. The pumps feature a high level of attention to hygiene and repeatability to reduce the risk of contamination. The downloadable Q-doc documentation, based on GDP (good documentation practice), provides full details of the product. This simplifies qualification, validation and change control to assure consumer safety. The pumps are said to be cost-effective, with maximum energy efficiency, a reduced CO_2 footprint, and provide higher yields and increased uptime. — *Alfa Laval AB, Lund, Sweden*
www.alfalaval.com

These progressive cavity pumps are now available in more sizes

Ideal for wear-intensive applications, the maintenance-friendly FSIP (full service-in-place) design of the NEMO progressive cavity pumps has been re-engineered to provide full access to all the pumps' rotating parts. NEMO FSIP is now available in six sizes (NM045 to NM105) for flowrates up to 700 gal/min. NEMO FSIP models are now offered with differential pressures up to 90 psi (for one stage) and up to 180 psi (for two stages). S, L, D and P geometries are now available. Users can conveniently open the in-service pump housing, dismantle all rotating parts and simply install them again without having to remove the pump from the pipe assembly or having to disconnect wiring. The rotor-stator unit can be lifted out after opening the newly designed inspection cover on the pump housing. In addition, the pump's installation footprint has been reduced for both conventional stators and the newer iFD-Stator. — *Netzsch Pumps & Systems GmbH, Waldkraiburg, Germany*
https://pumpen.netzsch.com

Laboratory pumps for high-pressure applications

This company has recently launched two new Smoothflow Q Series Pumps (photo, p. 27) for laboratory use, and they are now available for sale. One of the new pumps is a high-pressure type and the other is

Note: For more information, circle the 3-digit number on p. 86, or use the website designation.

an autoclave (AC) series designed for sterilization. The Q series pumps are small enough and light enough to be held in the palm of a hand, but powerful enough to provide discharge pressure up to 2.0 MPa, and precise enough to configure flowrates at units of 0.01 mL/min. The pump design allows for constant flow without pulsation, no liquid leakage or changes in properties, and because of its unique design, the pump is not damaged by dry running. They are suitable for dispensing, constant-cycle injection, gradient mixing, linked transfer of multiple liquids, flow-proportional injection and program control. — *Tacmina Corp., Schaumburg, Ill.*
www.tacminausa.com

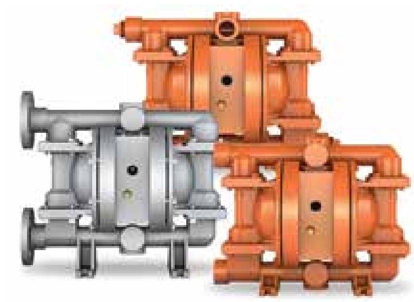
AODD pumps in three different materials of construction

Introduced last October, the PS220/230 FIT 25 mm (1 in.) metal air-operated double-diaphragm (AODD) pumps (photo) is equipped with the energy-efficient Pro-Flo SHIFT Air Distribution System (ADS), and available in three wetted-path materials of construction — aluminum, stainless steel and ductile iron. The new PS220/230 FIT pumps feature bolted product containment, easier maintenance and efficient operations. These pumps are shear sensitive and intrinsically safe with self-priming and dry-run capabilities, and offer the longest mean time between repair (MTBR), superior anti-freezing and increased on/off reliability. They are available with maximum discharge pressures to 8.6 bars, maximum flowrates to 254 L/min and maximum suction lifts to 6.9 m dry (9.0 m wet). — *Wilden Pump and Engineering, Grand Terrace, Calif.*
www.psgdover.com/en/wilden

Industry's first continuous-duty fuel-transfer pump

The Fill-Rite nextec Intelligence is said to be a first-of-its-kind, smart fuel-transfer pump technology that optimizes the fueling of fleet, construction and agricultural equipment. nextec Intelligence provides continu-

Tacmina



Wilden Pump and Engineering

GoatThroat Pumps

Wanner Engineering

MV Products

ous-duty for fuel transfer; accepts a range of power from 12 to 24 V supplies; requires a lower current draw; includes auto power down after 20 min. of inactivity to conserve power and prevent excessive wear; and monitors status and emits Intelligent Tones to identify specific pump conditions when attention is required. Pumping large volumes of fuel, filling large tanks or a number of vehicles typically requires stopping the pump every 30 min, explains the company. Now, with nextec Intelligence, the pump self-manages to maintain optimum performance and continuous operation. — *Tuthill Corp., Fort Wayne, Ind.*
www.tuthill.com.

Metering system for air-inventory reporting

This company offers two metering systems for data collection in support of required annual emissions reporting for EPA's Air Inventory Reporting, Toxic Release Inventory (TRI), Pollution Prevention (P2) and Greenhouse Gasses (GHG). Developed for a Federal Government Agency for point-of-use chemical delivery, the systems also substantially reduce fugitive air emissions, prevent chemical spills and mitigate worker exposure to hazardous liquids and emissions. The GT-M-N (photo) and the GT-M-K have different meters that are matched to the liquids for compatibility. These systems can be added to any existing pump system from this company, or can be factory installed on a new system. GT pumps typically have a service life of 10–15 yr, and provide for spill-proof, safe, virtually emission-free transfer of over 1,500 fluids and solvents. — *GoatThroat Pumps, Milford, Conn.*
www.goatthroat.com

This metering pump exceeds API 675 standards

The Hydra-Cell Metering Solutions model MT8 triplex metering pump (photo) is designed to handle a variety of processing fluids at low flowrates and high pressures. It features a multiple-diaphragm design to provide virtually pulse-free flow without the need for pulsation dampeners. The new MT8 pump exceeds API 675 performance standards for steady-state accuracy (±1%), linearity (±3%) and repeatability (±3%), the company states. Flow capacity for the MT8 ranges from a minimum of 0.06 gal/h to a maximum of 8.0 gal/h, with discharge pressure ratings up to 3,500 psi (241 bars), depending on flow. The integral relief valve protects the pump from overpressurization on the discharge side. The replenishment valve system in every piston ensures optimum actuating oil on every stroke for continuous accuracy and protects the pump from damage in the event of blocked suction. — *Wanner Engineering, Inc., Minneapolis, Minn.*
www.hydra-cell.com

These diaphragm pumps can take the heat

This company offers heat-resistant and heated-head diaphragm pumps that withstand temperatures up to 240°C. For sampling and analysis of hot gases and vapors, these heated-head pumps are designed to handle such high heat while maintaining a consistent media temperature. This feature prevents constituents from condensing out, ensuring more accurate results. The pumps also provide high gas-tightness, chemically-resistant flow paths, and flowrates to 180 L/min. Options include temperature control, temperature isolation, and alternative motors and materials. — *KNF Neuberger, Inc., Trenton, N.J.*
www.knfusa.com

Remove contaminants with these vacuum-pump inlet traps

The MV PosiTrap Vacuum Inlet Traps (photo) are made of stainless steel and are positively sealed at both ends to prevent "blow by" and protect vacuum pump fluids from acids, organic vapors, particulate matter and water vapor. Featuring a selection of filter elements, these traps are ideal for OEMs and end-users of gas analyzers, mass spectrometers and scanning electron microscopes to prevent the buildup of contaminants in the oil of roughing vacuum pumps. Available in 4- and 8-in. dia. straight-through and right-angle models that hold one and four filter elements each, MV PosiTrap Vacuum Inlet Traps can be changed in-line. — *MV Products, a Division of Mass-Vac, Inc., Billerica, Mass.*
www.massvac.com

Diffusion pumps become more energy efficient

This company has significantly reduced the energy consumption of the established DIP and newly developed DIJ diffusion pump series, with the aid of intelligent technologies and innovations. The new DIJ family (photo) features an optimized housing design, offering connections for both ANSI flange and ISO flange components, as well as various electrical connection variants. The new five-stage nozzle system of the DIJ series has been especially improved for the pressure range from 10^{-2} to 10^{-3} mbar. Through design changes and modern control elementsthe energy consumption of the diffusion pumps was reduced by an average of more than 30% — without sacrificing performance, the company says. — *Leybold GmbH, Cologne, Germany*
www.leybold.com

Transferring pure solvents in the semiconductor industry

The Futur S/SH air-operated diaphragm pump (AODP) series is now available in 316 stainless steel with high surface finish (photo) for the transfer of pure solvents in the semiconductor industry. Futur S/SH Series pumps are cleaned several times, then assembled and tested in a cleanroom line before being released for delivery. Futur S/SH Series pumps incorporate a straight-through flow pattern with only one wetted housing part, while the air-control system and the air chambers are located in the side housings. This design ensures that only one part of the housing comes into contact with the liquid, reducing the number of flow bends, minimizing the surface area, eliminating sliding parts in the product chambers and making it possible to eliminate the gaskets. The pumps are available in two sizes: 20 and 50 L/min. — *Almatec Maschinenbau GmbH, Kamp-Lintfort, Germany*
www.almatec.de

Two new sizes of internal-gear pumps

The E Series internal gear pumps (photo) are now available in 4- and 6-in. sizes, delivering flows up to 500 gal/min. Suitable for transfer applications, these new E Series pumps are available in cast iron, carbon steel and stainless-steel materials. The E Series pumps feature a revolutionary seal-less design with a patented between-the-bearing support system that effectively eliminates leaks and reduces mechanical wear, helping to increase the safety of site personnel and the environment. E Series pumps can handle viscosities up to 50,000 cSt. — *EnviroGear Pumps, Grand Terrace, Calif.*
www.envirogearpump.com

These sliding-vane pumps are alignment-free

The GNX Series sliding vane pumps (photo) are said to be the industry's first alignment-free, reduced-speed pumps for use in both portable and stationary applications. The design eliminates the couplings between the gearbox and the pump and motor by rigidly connecting them in alignment with a C-face (or similar) motor on both the high-speed and low-speed sides of the pump. The result is a pump that will not need to be realigned either at initial installation or following a maintenance procedure. These pumps are suitable for chemical-transfer applications because they are more efficient than competitive technologies, providing high-level performance, high suction lift and line-stripping capabilities with low maintenance and life cycle costs, says the manufacturer. — *Blackmer, Grand Rapids, Mich.*
www.psgdover.com/en/blackmer

Groundwater sampling pump tested PFC-Free

The Sample Pro Portable Pump has been tested to be free of perfluorinated compounds (PFC), a groundwater contaminant. Sample analysis by an independent laboratory showed no detections for 24 different PFCs at detection limits much lower than the U.S. Environmental Protection Agency (EPA) Health Advisory of 70 ng/L for PFCs under advisory. The Sample Pro Portable Pump combines the sample accuracy and high reliability of a bladder pump in an easy-to-use package. Its twist-open design makes it easy to change the disposable bladder in seconds. The pump's all-stainless construction will stand up to tough portable use. — *Q.E.D Environmental Systems, Inc., Dexter, Mich*.
www.qedenv.com ■

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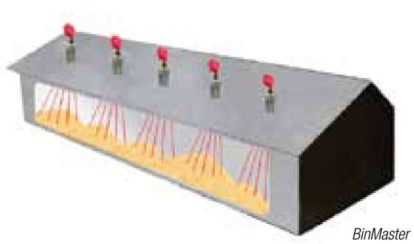
Leybold

Almatec Maschinenbau

EnviroGear Pumps

Blackmer

E Instruments International



BinMaster

Acromag

Lauda

Enable IIoT with this software solution

With the industrial internet of things (IIoT), it is essential that companies have an intelligent production-management system in order to obtain production information in realtime and store all the history in a database. CapTemp is a SCADA (supervisory control and data acquisition) software for monitoring a wide array of sensors and digital inputs. The application is end-user oriented, providing a user-friendly graphical interface. The software collects information from machines and delivers detailed reporting of all functions and required intervention, providing the data in realtime, and also stores all the information so that it is available in customized reports, listings and graphs. The data are presented so that they are easy to see, and the reporting can be customized to conform to all E.U. and U.S. regulatory agency requirements. — *CapTemp, Lda, Pombal, Portugal*
www.captemp.com

Collect and log combustion data with this hand-held device

The new E1500 hand-held combustion emissions analyzer (photo) is a rugged unit with the ability to measure CO and O_2 from high-efficiency and condensing boilers, burners, engines, turbines, kilns, furnaces, incinerators and other industrial combustion processes. Featuring a new, large color display and expanded internal memory, the E1500 lets operators easily see and save their sample data without worrying about running out of memory. The E1500 also features pre-calibrated, field-replaceable sensors that allow for easy diagnostics and replacement to reduce downtime and costly repair charges. — *E Instruments International, Langhorne, Pa.*
www.e-inst.com

Level monitoring in covered storage bunkers

Operations challenged with managing inventory in covered storage bunkers or flat warehouses have a new option that combines leading-edge software and the 3DLevelScanner acoustic sensor (photo) to measure the level of materials piled under structures. Multiple sensors measure and map levels across the material surface, while MultiVision software separates the piled material into virtual sections. Minimum, maximum and average levels per section are reported for up to 99 unique sections. The data is aggregated to output a visual showing the topography of the entire storage bunker. — *BinMaster, Lincoln, Neb.*
www.binmaster.com

A new family of signal splitters configured for easy setup

The new SP230 series of isolated signal splitters/duplicators (photo) are designed for easier installation and setup. Four models, covering a broad range of sensor signals, provide dual 4–20-mA outputs proportional to a single current, voltage or temperature input. A USB connection to a Windows PC or Android device enables simple, precise configuration of I/O ranges and a variety of operational settings with free software. The two-wire instruments include plug-in terminal blocks for quick installation and can acquire power from either output loop. Sink or source output wiring connections are supported. A ruggedized design operates reliably from –40 to 80°C with high immunity to electrical noise and surge protection. UL/cUL Class 1 Division 2, ATEX Zone 2 and IECex hazardous location approvals are pending. — *Acromag, Inc., Wixom, Mich.*
www.acromag.com

This thermostat cools down to –90°C

This company has extended its PRO portfolio to include two new low-temperature circulation thermostats designed for the specific requirements of test benches, reactors, climatic chambers and distillation plants in the CPI. With a temperature range of –90 to 200°C and a cooling capacity of 0.8 kW, the RP 290 E and RP 290 EC low-temperature circulation thermostats (photo) are ideal as a substitute for dry ice in external low-temperature applications. The new models offer a cooling capacity of 1.5 kW, almost twice the capacity of the RP 245 (0.8 kW), which was previously the most powerful model, with the same space

Siemens AG

Prüftechnik Dieter Busch

requirements. — *Lauda GmbH & Co. KG, Lauda-Königshofen, Germany*
www.lauda.de

New generation of soft starters for all drive requirements

The Sirius 3RW5 range (photo) is a new generation of soft starters for simple to demanding drive requirements. This comprehensive range of devices for the soft starting of three-phase asynchronous motors from 5.5 to 1,200 kW enables efficient and future-proof machine concepts to be implemented easily and cost-effectively, says the manufacturer. The new Sirius 3RW5 soft starters are suitable for any drive, they can be easily integrated into the automation system, and they supply data directly to MindSphere, this company's cloud-based, open IoT operating system. Practice-related functions (such as automatic parameterization with changing startup characteristics) and integrated properties (such as electrical ruggedness in the case of fluctuating line voltages) support smooth operation in a host of applications. — *Siemens AG, Munich, Germany*
www.siemens.com

A new breakthrough in vibration monitoring

Together with the new high-speed data collector Vibscanner 2, this company launched a major new release of the OMNITREND Center software (photo). This is the central PC software for the company's handheld vibration instruments and online condition monitoring systems. The new version offers intuitive software tools for generating a clear and structured overview of the monitored assets. In the redesigned graphical user interface, engineers can easily create and configure the assets as they are in the field. More highlights, such as easy graphical machine setup, central task configuration, flexible route management and advanced analysis tools, will slash the learning curve for new users and allow experienced analysts to save extra time, says the company. The new interface has advanced diagnostic tools that are easy to use. — *Prüftechnik Dieter Busch AG, Ismaning, Germany*
www.pruftechnik.com

Software for interfacial analysis now with touch operation

Touch displays are currently gaining ground in the laboratory environment, since they save on space and are easy to clean — keyboards are generally unsuitable for the laboratory bench. Therefore, the new version of ADVANCE software for interfacial analysis (photo) features all the contact angle measurement, tensiometry and foam analysis methods ad-

justed to touch-sensitive monitors. The new ADVANCE version works with two alternative user interfaces that are optimized for both touch or mouse and keyboard operation. The company is now also offering licenses for ADVANCE with Software Assurance. — *Krüss GmbH, Hamburg, Germany*
www.kruss-scientific.com

Hygienic magnetic mixer for life-science applications

The MBE Series MagMixer (photo) has been specifically designed for reliable operation and regulatory compliance in life science applications. The unit has no shaft penetrating the tank and so requires no mechanical seals, which significantly reduces the risk of leakage or microbial contamination. It provides high torque capacity with optimum cleanability and, with bottom-mounted magnetic agitators, is ideal for low-viscosity blending, dissolving solids and solid suspension in sterile applications. The MagMixer MBE utilizes Lightnin A281 3-blade hybrid axial/radial impellers in an open construction that maximizes flow while facilitating easy cleaning and sterilization. Alongside optimizing product flow, the impellers contain strong magnets that produce high levels of torque capacity in a compact form. The magnetic impeller removes the need for shaft and seals. Strong, oversized ceramic bearings reduce the risk of breakage, are product lubricated and produce exceptional mixer stability, reliability and performance. The mixer is controlled by a variable frequency drive (VFD) with operating speeds between 200 and 1,000 rpm. — *SPX Flow, Inc., Charlotte, N.C.*
www.spxflow.com

Spherical vacuum dryer for hygienic drying applications

Hygienic drying in a vacuum requires many attributes. The innovative spherical dryer design (photo) provides the highest performance, according process control and the latest GMP standards. This company is currently delivering several units for hygienic drying. The spherical dryer in Rosenmund design delivers fast drying, mixing and granulation; is easy to clean; has total product discharge; and short drying time due to its high heat-transfer design. The lower half of the sphere is removeable either by pivoting or dropping. This allows total and full visual and manual access to the process area. The accessibility, cleanability and a fast and residue-free discharge are the most important prerequisites for the production of high-quality products. Effective trouble-free washing and cleaning (WIP/CIP) are required to maintain the systems in order to meet strict hygienic standards. — *De Dietrich SAS, Strasbourg, France*
www.dedietrich.com

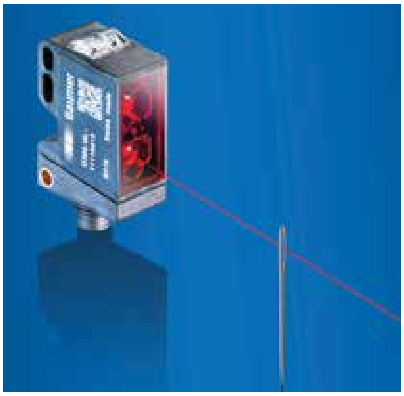
Miniature laser sensors with IO-Link for flexibility and control

The new O300 miniature laser sensors with IO-Link (photo) reliably detect very small objects and gaps. With their IO-Link integration, O300 laser sensors are Industry 4.0-ready. IO-Link allows the quick and easy configuration of sensors for all applications using standard network components. Additional data, such as for predictive maintenance processes, are available for evaluation. IO-Link makes these sensors ideal for object detection applications in the assembly, pharmaceutical and process automation industries. Due to a laser beam, which focuses to within 0.1 mm and a high repeat accuracy of 0.1 mm, objects can be positioned with high precision and follow-up processes controlled exactly. With an extremely short response time of less than 0.1 ms, the sensor reliably detects even closely spaced objects, thus allowing fast processes and high throughput rates. Another advantage of the device is the exact alignment of the laser beam to the mounting holes by design (qTarget). qTarget ensures guaranteed detection with pinpoint accuracy over the entire series. Stainless-steel variants in a rugged washdown and hygienic design extend the typical applications of the O300 laser sensors to packaging plants in the food and pharmaceutical industries.— *Baumer Electric AG, Fraunfeld, Switzerland*
www.baumer.com

Krüss GmbH

SPX Flow

De Dietrich



Baumer Electric

Sartorius Stedim Biotech

Epson Labelworks PX

Single-use perfusion system for cell culture process development

Last month, this company launched the ambr 250 high-throughput (ht) perfusion (photo), a new automated parallel bioreactor system. It has been specially designed for rapid cell-culture-perfusion process development to optimize production of therapeutic antibodies. The ambr 250ht perfusion system was developed in collaboration with major biopharmaceutical companies. It combines 12 or 24 single-use perfusion mini bioreactors (100–250 mL working volume) with associated single-use perfusion components, all controlled by one automated workstation. The combination of this multi-parallel processing capacity and fully single-use perfusion vessel enables scientists to perform more perfusion culture experiments in a fraction of the time and cost of using traditional perfusion-enabled benchtop bioreactors. This new innovation supports a range of hollow-fiber perfusion applications, enabling design of experiments (DoE) studies for high-cell-density process development in a quality by design (QbD) approach. — *Sartorius Stedim Biotech, Göttingen, Germany*
www.sartorius.com

This hand-held device labels and identifies components

The new PX LW-PX300 (photo) is a portable wire-marking, barcode and general-identification printer for creating custom and compliant labels up to 3/4-in. wide. The device can be used to identify wires and equipment, organize tool cribs and storage bins, make safety labels, tag assets and more. The LW-PX300 allows users to quickly print batches of sequenced labels by printing the first label, waiting for the user to cut the label, and then printing the next label in the sequence for faster print-and-apply tasks in the field. — *Epson Labelworks PX, Somerset, Wisc.*
https://labelworks.epson.com ■

Gerald Ondrey

Corrosion complications

Department Editor: Scott Jenkins

Corrosion is an obvious factor to consider when selecting materials of construction for process equipment. However, the chemical environment of the process is only the starting point in selecting an acceptable material. A set of other factors can complicate corrosion-resistance strategies. This one-page reference summarizes several of these areas.

Impurities

The corrosive properties of a process fluid's major constituents are usually known to process engineers. Less obvious, however, may be how the presence of impurities can cause corrosion. Here several examples:

Chloride ions. An example of a harmful impurity is the chloride ion, which, under certain conditions, is known to cause stress-corrosion-cracking (SCC) and pitting of stainless steels. This insidious form of corrosion can occur at concentrations as low as a few parts per million. The negative influence of contaminating chloride and fluoride ions on steel's corrosion resistance is amplified at higher temperatures. Increases of 10°C can almost double the corrosion rate.

Corrosive gases and airborne contaminants. Airborne contaminants can include the following: airborne liquid droplets, including small levels of condensation and sea salt mist; solids, including grit, sand and dust; and gaseous species, including active sulfur, oxides of sulfur, gaseous chlorine, oxides of nitrogen, hydrogen fluoride, ammonia, ozone and strong oxidants. These can present potential corrosion issues, especially in the context of degrading critical electronic equipment.

Corrosion of metals by gaseous contaminants is accelerated by heat and moisture. Rapid shifts in either temperature or humidity cause electronics or other components to fall below the dewpoint temperature, thereby allowing condensation of contaminants. In the context of electronics, relative humidity (RH) above 50% accelerates corrosion by forming conductive solutions. Microscopic pools of condensation then absorb contaminant gases, which become electrolytes in the pools, where crystal growth and electroplating occur. Above 80% RH, electronic corrosive damage will occur, regardless of the levels of contamination. Prime culprits in the corrosion of electronics include acidic gases, such as H_2S, chlorine and HF, NO_x and SO_x; as well as caustic gases, such as NH_3; and oxidizing gases, such as O_3. Acidic gases are typically the most harmful. If the operation is maintained at a temperature above the dewpoint, the corrosion rate drops to almost nothing.

Microbes. Bacteria cause a type of corrosion known as microbiologically influenced corrosion (MIC), whereby the bacteria can eat through stainless steel tanks and piping. Bacteria primarily attack the retained, ferritic, metallic grains in stainless weldments, although MIC can also occur in the base metal, remote from welds. The bacteria burrow caves into the metal that, when observed with a scanning electron microscope, appear like a honeycomb structure (see Figure 1). Most commonly used metals are subject to MIC attack to varying degrees.

Air and O_2. The presence or absence of air (oxygen) may also affect the corrosion resistance of a material in a specific environment. The presence of O_2 or the occasional exposure to air may be necessary to maintain the protective oxide films on materials, such as stainless steel, which depend on a chrome-oxide film for corrosion resistance. On the other hand, the presence of air may destroy the corrosion resistance of a material that is normally not corroded in a reducing, O_2-free chemical environment.

Boiler feedwater is a good example. A boiler can fail in six months if O_2 is present in the boiler feedwater. The same boiler could last six decades with deoxygenated feedwater.

Flow

Flow velocity must be evaluated, particularly when considering pumps, agitators, and other equipment subjected to relatively high fluid velocities. Velocity can manifest itself in a corrosive environment as flow-accelerated corrosion (FAC). Of concern here is the fact that most published corrosion data are based on relatively stagnant corrosion conditions. Although there are a few exceptions, corrosion increases as velocity increases. An example is commercial-grade ambient-temperature sulfuric acid transport in carbon steel. One notable exception is that flowing water inhibits MIC.

Briem Engineering

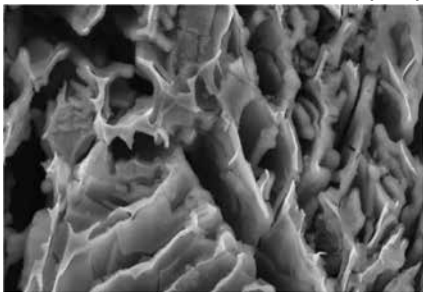


FIGURE 1. This image from a scanning electron microscope shows microbially induced corrosion in steel

pH

In general, lower pH means more aggressive corrosion. A variation in pH of a few points could make the difference between being able to use a relatively inexpensive material and requiring a costly material of construction. For example, a lower pH environment allows SCC to occur at a lower chloride concentration.

Cleaning/sanitizing operations

The procedure and frequency with which the process equipment will be cleaned and sanitized should be considered. It is not unusual for the cleaning operation to corrode processing equipment. Periodic cleaning with steam and cleaning agents can corrode processing equipment even though the basic production environment is noncorrosive. ■

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LDPE via a High-Pressure Tubular Process

By Intratec Solutions

Polyethylene (PE) is the world's largest-volume commodity polymer, due in large part to the widespread availability of ethane, the raw material for manufacturing ethylene, as well as ethylene's relatively low cost and broad range of applications. Low-density polyethylene (LDPE) is one of the three main types of polyethylene. The other two are high-density polyethylene (HDPE) and linear low-density polyethylene (LLDPE). LDPE differs from HDPE and LLDPE primarily in its unique molecular structure — large amounts of long-chain branching impart the material with different rheological behavior in both shear and extension.

The process

The following paragraphs describe a high-pressure polymerization process for the production of LDPE, using tubular reactors. Figure 1 presents a simplified flow diagram for this process.

Compression. Fresh polymer-grade ethylene is mixed with a low-pressure gas stream that contains unreacted monomer recovered from downstream in the process, and is fed to the primary compressor. There, the ethylene is compressed to 300 bars. The ethylene stream from the primary compressor is mixed with chain-transfer agents and recycled ethylene monomer and fed to the secondary compressor, where it is compressed to 3,000 bars, the reactor operating pressure.

Reaction. The compressed ethylene is divided into several streams and fed into the tubular reactor at several different injection points. The organic peroxide solutions from the initiator feed system, which are also injected at multiple points along the length of the reactor, initiate the polymerization reaction. The reaction is carried out at a high temperature (220°C) and high pressure (3,000 bars). Reaction heat is removed by the following: (a) increasing the temperature of ethylene, (b) adding fresh monomer in side-stream entry points, and (c) by heat-transfer through a jacketed water-cooling system.

Separation. The reactor outlet is expanded to 300 bars (absolute) and fed to a high-pressure separator, where unreacted ethylene gas is removed from the polymer by adiabatic flash. The molten polymer phase from the bottom of the high-pressure separator is routed to the low-pressure separation section. Here, the molten polymer phase passes through an additional flash step, in which remaining unreacted ethylene is removed.

Extrusion and pelletizing. The molten polymer and additives are fed to a short single-screw extruder with an underwater pelletizer. Here, the mixture is pelletized and then conveyed to silos for homogenization. The pellets are sent to bagging silos that serve the stationary bagging and packaging lines. At this point, LDPE product is packed into bags.

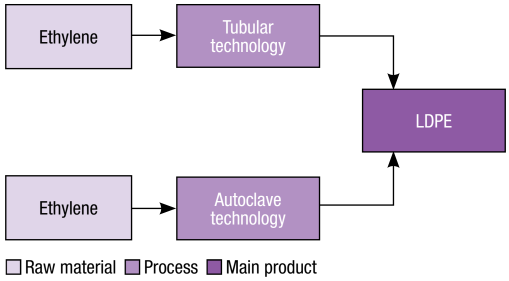

FIGURE 2. There are two possible production routes to LDPE

Production technologies

LDPE production involves the polymerization of ethylene, carried out generally through either tubular or autoclave technologies (Figure 2).

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) to produce LDPE was estimated to be about $1,480 per ton of LDPE in the second quarter of 2014. The analysis was based on a plant constructed in the U.S. with capacity to produce 400,000 metric ton per year of LDPE.

This column is based the report "LDPE via High-Pressure Tubular Process – Cost Analysis," published by Intratec. It can be found at the following URL: www.intratec.us/analysis/ldpe-production-cost. ■

Edited by Scott Jenkins

Editor's note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are prepared on the basis of publicly available and non-confidential information. The content represents the opinions of Intratec only. More information about the methodology for preparing analysis can be found, along with terms of use, at www.intratec.us/che.

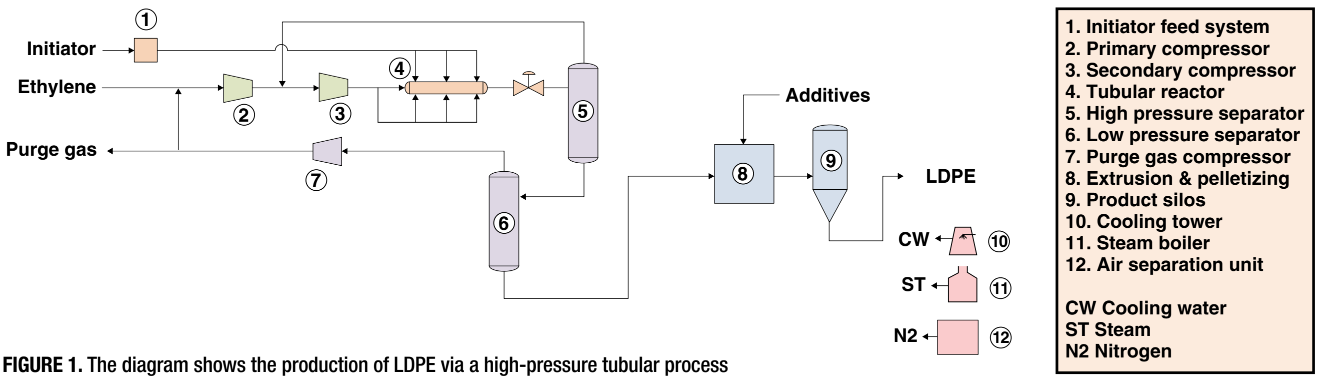

FIGURE 1. The diagram shows the production of LDPE via a high-pressure tubular process

Taking Representative Samples in Solids-Handling Processes

Non-representative sampling in solids processes has costly consequences. A better understanding of the mathematical basis for sampling and of acceptable quality levels can help to alleviate potential sampling issues and more closely approximate reality

Alan F. Rawle
Malvern Panalytical

IN BRIEF

- HISTORICAL CONTEXT
- STANDARD ERROR IN SAMPLING
- SAMPLING BIAS
- PARTICLE SIZE ANALYSIS
- SAMPLE SIZES
- SAMPLE COLLECTION
- CONCLUDING REMARKS

Effective sampling in solids-handling processes is critically important to process success and product quality. Conversely, the negative consequences of non-representative sampling are potentially immense. Despite the importance of sampling, the attention placed on ensuring proper sampling and the resources devoted to it are commonly disproportionately small compared to the efforts directed elsewhere. Further, effort aimed at understanding the mathematical basis associated with minimum mass requirements and standard error is generally lacking. For example, the first chapter of Terry Allen's classic book "Particle Size Measurement" [*1*] addresses representative sampling, but is often ignored in pursuit of other more "interesting" chapter topics. Consider that errors caused by non-representative sampling have massive economic impact — one example is quoted at $134 million loss over 10 years in a mining project [*2*].

There are several adages, quotations and clichés from the field of statistical sampling that can be aptly applied to solids-handling technology. The concepts held in these adages can help frame the discussion of solids sampling. One particularly insightful quote from solids engineer Mark Murphy states "all samples are wrong — some are more wrong than others." This quote gets at the error inherent in sampling and the idea that engineers must define their tolerance for error.

FIGURE 1. Non-representative sampling led to incorrect predictions in the 1948 U.S. presidential election. Election polling offers a way to study standard error, a concept that is important in sampling for solids processes also

Most of us are familiar with the phrase "garbage in equals garbage out," perhaps more elegantly phrased by Francis Pitard's quote "Your decisions are only as good as your samples." This quote expresses the concept that the quality of analytical results depends on the sample size that is analyzed.

The pragmatic engineer needs to get a feel for the minimum sample masses needed to meet a given specification or acceptable quality level (AQL). This practice is part of what this article explores. In addition, the article attempts to help close the gap in appreciation and understanding of representative sampling by investigating the theory and practice of sampling particles for analysis of solids processes.

Historical context

It was really the end of the 1880s that mining engineers started to take a keen interest in sampling issues. At the time, the realization took hold that separate analyses of gold-bearing ore in particular could have profound effects on the remuneration of the ore seller.

Warwick [*3*] quotes an example where Assayer 1 indicates 79 ounces per ton of gold and Assayer 2 indicates 11.5 ounces per ton for the "same (divided) pulp sample." At that time (1903), this discrepancy amounted to a difference of $1,350 per ton. With hindsight, we can see that both can be right — the gold nugget sitting in one half of the pulp sample obviously affects the difference between the two halves.

The analytical errors are at least two orders of magnitude lower than those potentially introduced by non-representative sampling. This means that we should be spending two orders of magnitude more dollars on the sampling equipment in plants than the analytical tools that deliver high accuracy and high precision on tiny amounts of sample. Transmission electron microscopy springs to mind as a user of tiny sample amounts.

Alan Rawle

The simplest rule, adopted by Vezin[14] in 1866, is: first, to decide what weight (w) should be taken for assay or analysis after the ore has been ground to 100-mesh (approximately 0.125 mm. diameter); second, to compute the number (n) of maximum sized grains passing through a 100-mesh screen that would weigh (w); and third, to cut down to a weight after each crushing which will be equal to n of the maximum sized particles.

This rule may be said to use a constant number of particles whatever their size. The following figures show the weights of different sizes required by this rule on the basis of 0.1 assay ton (2.917 grams) of ore through a 100-mesh screen (0.125 mm.):

128	mm.	3,131	metric	tons.
64	"	391	"	"
32	"	48.9	"	"
16	"	6.12	"	"
8	"	764.6	kilos.	
4	"	95.57	"	
2	"	11.95	"	
1	"	1.493	"	
0.5	"	186.7	grams.	
0.25	"	23.33	"	
0.125	"	2.917	"	

The above rule demands finer crushing than practice indicates to be necessary, and it is, therefore, more expensive than is wise. The sampling works and assayers have made approximations to rules deviating from the above, to save the excessive cost, and yet be accurate enough for purposes of buying and selling;

FIGURE 2. Historical work in statistical sampling led to a situation in which the amount of solid material needed for statistical validity has been chronically underestimated [*6*]

Election poll predictions is another area worth examining as an example that brings a mathematical perspective as a starting point, because it illustrates practical guidelines that help build understanding of other traditionally technical areas.

In the 1948 U.S. presidential election between Thomas Dewey and Harry S. Truman,

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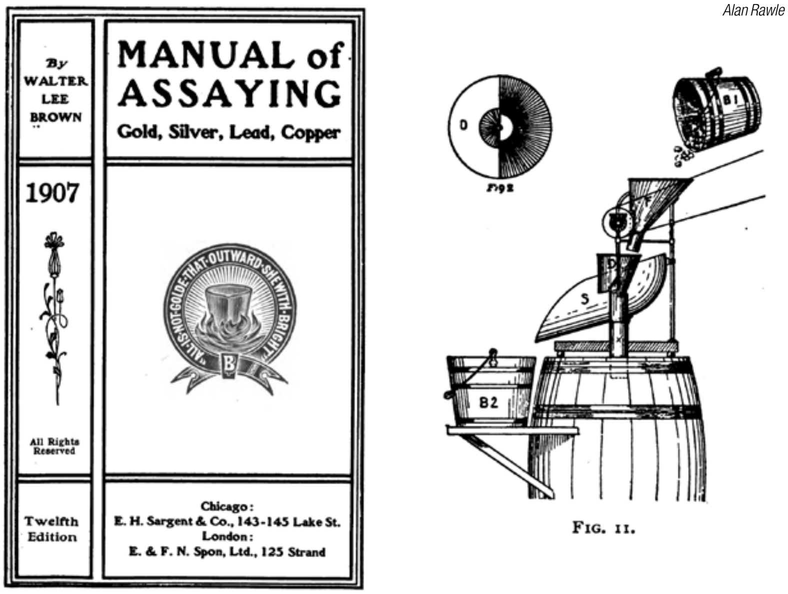

FIGURE 3. The spinning riffler technique, known in the early days of mining, generates a low standard deviation for repeated samples

the polls predicted the results so poorly that a smiling Truman was captured in a now iconic photograph holding up a newspaper trumpeting the incorrect outcome (Figure 1).

What went wrong in this case? The conclusion of many commentators at the time was that "non-representative sampling" caused the incorrect result be predicted. This may or may not be true, and we will revisit this case later in the article. How do voting polls relate to particle size analysis? Noted engineer and statistician W. Edward Deming, a sampling pioneer, and his mentor Walter Shewhart spent a lot of time studying poll analysis in the 1930s (before the Truman election referred to above). These two individuals are well known in the area of quality control circles. So did they get it wrong when it came to the 1948 election?

The answer is "of course not." In both voter polling examples and in particle size distribution examples in solids handling, the math is relatively simple, and the explanation of what happened requires a look at the concept of standard error (the standard deviation of the sampling distribution).

Standard error in sampling

The standard error is proportional to $1/\sqrt{n}$, where n is the number of people interviewed, or the number of experiments, or the number of particles in a particle-size distribution, and so on. Standard error (SE) is the measured standard deviation around a mean value for repeated samplings. The larger the size of the sample that is taken, the nearer the measured result will come to the correct result or "truth." The rule of thumb for these situations is that there is a roughly two-thirds (68%) probability that the "truth" (actual value) for a given sample will lie within ±1 SE of the measured or sampled mean.

The following example can help illustrate this. Imagine that an election is close — 52% to Candidate A and 48% to Candidate B. It is not possible to determine the actual outcome of the election before all the votes are counted, but by taking a representative sample of the voting results, we can predict the ultimate outcome before all the votes are in. Now imagine a random and representative sample of 1,000 voters in this fictional election. This number sounds a lot — at least it will be a lot of work for the company conducting the voter interviews.

In this case, the SE would be $1/\sqrt{1{,}000}$, or approximately 3.2%. This means that the measured value will have an error associated with it of around 3%. For a normal (Gaussian) distribution, then 68% (roughly two-thirds) will lie within ±1 SE of the measured mean. Thus the "truth" will be within this range 68% of the time. For this election example, it means that the margins of error for the 1,000-person representative sample would be 48 ±3% and 52 ±3%. In a tight election, this error margin is enough to swing the election the other way. And this margin or error represents only one standard error. To achieve 95% confidence, we would need ±6%. Many elections are decided by smaller margins than this. To reduce the margin of error to ±1%, we would need to have a random and representative sample size of

TABLE 1. SAMPLE CALCULATION FOR MASS OF SILICA PARTICLES

Diameter, µm	Diameter, cm	Density, g/cm³	Mass of top size fraction, g	Total weight, g (= last column × 100)	
1	0.0001	2.5	0.000000013	0.00000131	
10	0.001	2.5	0.000013	0.00131	~1 mg
100	0.01	2.5	0.013	1.31	~1 g
1,000	0.1	2.5	13.090	1,309	~1 kg
10,000	1	2.5	13,089.969	1,308,997	~1,000 kg
			This is the mass of 10,000 particles	This is where 1% of the particles are in the top size band	

10,000 people. So whether you are interviewing voters or analyzing a particle size distribution in a solids process, the prerequisite question before sampling begins must be "What precision is required?"

Sampling bias

The error margin discussed previously assumes a perfectly representative sample, but what if other factors are at work to increase the error? Continuing with the election example, the inaccuracy of the results can grow substantially if the sample is not truly representative, or if the election polls themselves influence the number of people that vote in the actual election, or if people in the sample have lied to the interviewer about how they placed their vote.

For an example of bias, consider another example. Imagine that pollsters decided to conduct the poll by making phone calls to 1,000 people listed in the telephone directory. Doing so would undoubtedly generate potential problems that would threaten the accuracy of the results. For example, voters in the Millennial generation would be underrepresented because they have lower rates of ownership of "landline" phones, favoring wireless mobile phones. Also, the time of day for the polling call could affect results – daytime calls would miss people who work away from home. Further, the sample would not include voters who could not afford a telephone.

Undecided voters can also affect errors because they may provide one answer in the pre-election interview, only to change their minds by the time they get to the election booth. The pool of undecided voters can be very large in some elections.

And if the sample of interviewed people is not representative in the first place, then the results will be worse. Switching to an analogy in solids handling, the phenomenon of segregation can cause the sample to be non-representative. When this is the case, we enter the "garbage in equals garbage out" scenario, and decisions may be based on faulty data.

FIGURE 4. The Jones-type riffler sampling device, and its variants, were mentioned in several ASTM standards. The photo is from Ref. 7.

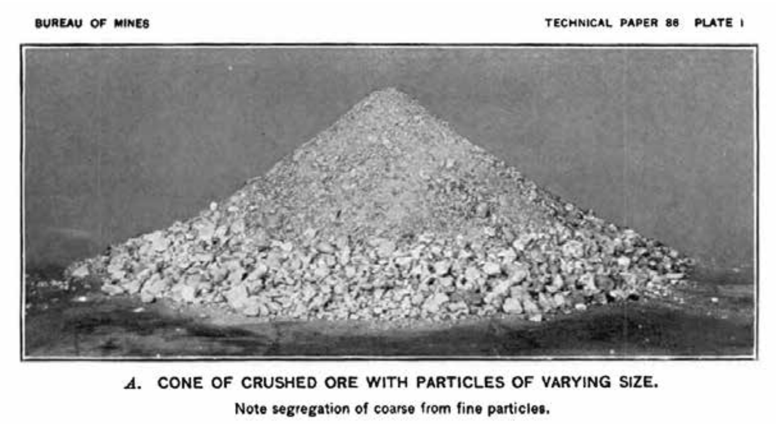

FIGURE 5. Early mining photos show the segregation of particles with varying sizes

Particle size analysis

For solids handling, the question now becomes how to link the sampling information to particle size analysis. With a particle size distribution, it is tempting to think that we can specify it exactly with a sample. The key word is "distribution," which implies that there is a true value with an associated margin of error. As geochemist F.J. "Father" Flanagan stated in 1979 [*4*], most of the methods relating particle size, sampling errors, and the amount of analytical sample to be taken may be used to do the following:

- Calculate the error that might be incurred, given a specified weight of sample
- Specify the sample amount to be taken to keep sampling errors at or below some level
- Specify the grain size to which a sample must be crushed so that significant sampling errors may be avoided

Flanagan further states: "Calculations by most methods should show that errors due to sampling heterogeneous materials may be ignored if the material is powdered to pass a 200# (75 µm) sieve or, for Kleeman (1967), a 230# (63 µm) sieve." We will examine why this is the case when we address the minimum mass question subsequently.

First, consider a "worst-case" situation. Imagine that we want to specify the x_{99} point of the size distribution to a precision of 1%. The term x_{99} refers to the point in the size distribution at which 99% of the particles are smaller than a given size (x) and 1% are greater. Related terms could be x_{90} (90% less than the size x, and thus 10% greater); x_{50} (50% above and 50% below size x: the median), and so on.

What implications would this have? As stated previously, the standard error is inversely proportional to the square root of the number of particles (S.E. $\propto 1/\sqrt{n}$ or $n \propto 1/\sigma^2$). For a 1% S.E., $n = 1/(0.01)^2 = 10{,}000$. Therefore, a total of 10,000 particles total would be needed to specify the mean to 1% S.E. To specify the x_{99} to 1%, 10,000 representative particles would be needed in the x_{99+} point of the distribution. These 10,000 particles only make up 1/100th of the total mass of the system (because 99% of the volume and mass is below the x_{99} point). The total minimum mass could therefore be found by calculating the mass of 10,000 particles at the x_{99}+ part of the distribution and multiplying by 100 to arrive at the total minimum mass.

To calculate masses, an assumption must be made about particle shape, so a starting point could be the sphere (the most compact shape). The volume of a sphere is $(\pi/6) \times D^3$ and the mass of a single particle is the volume multiplied by the density. We can calculate the mass of 10,000 particles of the appropriate density at a known or assumed x_{99} point. It is straightforward to spreadsheet the calculation for silica, for example (~2,500 kg/m^3). The cgs (centimeter, gram, second) unit system is slightly easier to use in this regard than the SI mks (meter, kilogram, second) system (Table 1).

This now gives us a convenient framework to estimate the minimum sample masses required for any degree of precision that is desired. Note that we need roughly 1 g of sample at 100 µm (for the x_{99} point) and that many instrumental techniques take ~1 g or less of sample. Thus, the earlier comment by Flanagan is easy to understand in this context. Also, it is important to note that the largest particles are the most important in sampling issues, and attempts to find a small number of large particles may be akin to the "needle-in-a-haystack" situation.

However, if the x_{90} (rather than x_{99}) is required to achieve a SE of 5%, then the mini-

TABLE 2. CALCULATION FOR PHARMACEUTICAL EXAMPLE

Dia., µm	Dia., cm	Density, g/cm^3	Weight in top size fraction, g	Total weight, g (= last column × 100)
1	0.0001	1.5	7.9×10^{-9}	0.00000079
10	0.001	1.5	7.9×10^{-6}	0.00079
100	0.01	1.5	0.0079	0.788
200	0.02	1.5	0.063	6.3
500	0.05	1.5	0.99	98.5
1,000	0.1	1.5	7.9	788
1,500	0.15	1.5	26.60	2660
2,000	0.2	1.5	63.1	6,305.2
10,000	1	1.5	7,881	788,148
			This is the weight of 10,000 particles	This is where 1% of the particles are in the top size band
			Assuming spheres	

TABLE 3. REVERSE CALCULATION RELATING STANDARD ERROR TO NUMBER OF PARTICLES

D ia., μm	Dia., cm	Density, g/cm^3	Mass used, g	Mass of one particle, g	Number of particles in 1/100 of the sample mass	Calculated SE, %
1	0.0001	1.5	0.02	7.85398×10^{-13}	254,647,909	0.006
10	0.001	1.5	0.02	7.85398×10^{-10}	254,648	0.20
100	0.01	1.5	0.02	7.85398×10^{-7}	255	6.27
1,000	0.1	1.5	0.02	0.000785398	0.3	198
2,000	0.2	1.5	0.02	0.006283185	0.03	560
5,000	0.5	1.5	0.02	0.09817477	0.002	2216
10,000	1	1.5	0.02	0.785398163	0.0003	6267
				$(\pi/6) \times D^3$		% SE = $100/n^{0.5}$

mum mass in the last column is reduced by a factor of 250 (the x_{90} point, which represents 10% of the total mass of the system). G. Herdan [*5*] states: "Sampling by small weights is notoriously conducive to throwing overboard larger pieces" and ". . . the smaller the weight, the greater, on the whole, the shift in the distribution mode or peak toward the smaller particles."

For historical reasons, the amount of material needed for statistical validity in sampling has been underestimated. We can set this issue at the foot of Robert Hallowell Richards, an MIT professor. In his classic set of four volumes on ore dressing published in 1908 [*6*], there is a very important table (Figure 2) and a comment that have had a great influence throughout the history of sampling. It is worth examining this table and comment in detail.

Richard's comments underneath the table are the following:

- "The above rule demands finer crushing than practice deems to be necessary

Jenike & Johanson

FIGURE 6. This model of a non-homogeneous mixture of solids from Jenike & Johanson provides a good visual representation of segregation during solids-handling processes

TABLE 4. STANDARD DEVIATIONS BY SAMPLING TECHNIQUE

Reliability of selected sampling methods using a 60:40 coarse/fine sand mixture

Sampling technique	Standard deviation
Cone and quartering	6.81
Scoop sampling	5.14
Table sampling	2.09
Chute slitting	1.01
Spinning riffling	0.146
Random variation	0.075

From Ref. 1, Table 1.5, p. 38.

and it is therefore more expensive than it is wise"

- (And later on in the chapter) "By adopting the rule that the weight shall be proportional to the square of the largest particles, we obtain a set of figures that will in all probability meet the approval of practicing engineers . . ."

So Robert H. Richards is essentially stating that weight is proportional to the square of the diameter, and it was this that set sampling theory back for over 50 years, until French statistician and chemist Pierre Gy was able to retrieve the statistical situation in the 1950s and onward.

The powerful nature of Gy's statistical approach, known as "Theory of Sampling" (TOS), is that it allows us to calculate the best standard error or variability based solely on the heterogeneity of the material. This is simply a reversal of the minimum mass calculation described earlier.

Consider this real-world example. A pharmaceutical manufacturing engineer believed that she had up to 1% of 2,000 µm particle size material in a pharmaceutical slurry containing 20% solids by volume. She wanted to be 99% confident of this assertion. Using a spreadsheet for the calculation as earlier, and assuming a density of 1.5 g/cm^3 for the pharmaceutical solid, the results would be those found in Table 2.

The calculated mass is around 6.3 kg, which represent more than 30 L of 20% slurry. This result can be considered in another way: as the minimum amount of material required to have homogeneity at the 99% confidence level. Each 30 L portion will be statistically equivalent (99% confidence limits) or homogeneous. Even if we are sampling 100 mL at a time (300 samples), we would expect 299 negative tests and only one positive. A single test, or even 10 repeated samplings, could not state with statistical certainty that 1% of the universe of material was at 2,000 µm particle size. The entire 30 L needs evaluating.

This is what statistical quality control is about, hence the use of process analytical technology (PAT) and on-line/continuous verification of production uniformity in the pharmaceutical arena. When informed that 30 L of slurry was required to meet her requirements, the aforementioned pharmaceutical engineer replied, "I can only afford 20 mg for a test."

A reverse calculation shows the best standard errors based on 20 mg of solid material. The concept is to calculate the mass of a single particle: $[\pi/6] \times D^{3*}\rho$, where ρ is the density of the sample — and then to calculate the number of these particles that fall into the appropriate part of the size distribution. Thus for 20 mg of total sample, the x_{99}+ point would represent 1/100 of this total mass (0.002/100 or 0.00002 g). If we calculate the number of appropriately sized particles in this amount of sample, we would have the relationship between the number of particles and the standard error (S.E. $\propto 1/\sqrt{n}$ or $n \propto 1/\sigma^2$) (Table 3).

For a 2,000 µm particle size and 20 mg of sample, the best that can be achieved is 560% standard error because a 20-mg sample of material does not, on average, contain even a single 2,000-µm particle at the x_{99}+ point. This would be considered a specimen, rather than a (representative) sample. If this large particle creates a difficulty for the process or product, it would be far better to try to filter it out before the point of use than to try to "inspect it in."

Another practical example arose when lunar regolith and simulants were measured for particle size distribution. Because the "moon dust" is a national treasure, researchers are only permitted small quantities to measure. For an x_{95} point of around 450 µm (a realistic point for the top end of lunar regolith), the best standard error achievable for 20 mg of sample (ρ ~2.73 g/cm^3) is about 36%. It's no wonder that large variations were seen in replicate particle size determinations.

Sample sizes

Sample errors rise markedly as the size of the solid increases – a result of the fact that mass is a cubic function of size. Again, we see the importance that small numbers of large particles may have on the calculated size distribution and standard error.

As South African mine engineering professor RCA Minnitt put it when talking about sampling for mining applications: ". . . However, that's not all. At the end of a very careful preparation protocol, the analyst will extract

exactly a 30-g aliquot of material from the finely milled powder for fire assay. Twenty-seven such assays would amount to just 810 grams of rock powder. One metric ton (m.t.) is equivalent to 1,000,000 g, so 810 g is 0.00081 m.t. to evaluate 67 m.t. of rock." Minnitt goes on to say that "Putting that into context, this means that we are trying to represent the 9,000 billion cm^3 in this room using a volume about the size of a pinhead."

Pierre Gy's Theory of Sampling (TOS) school has two camps in defining this variability. Some prefer using the term "error," because it implies that someone is culpable (usually management who has failed to deliver the tools for the job and has over-specified the needs), while others prefer using the term "variability" to express the idea that the standard error numbers reflect the natural variation in the system that cannot be improved upon.

In the author's work with clients, it is often observed that they want to use only a tiny amount of their "expensive" material as a sample. Using this small amount is akin to sampling the contents of a desk by removing a single pen. If a smaller-than-the-minimum mass is taken, the margin of error increases. The only reasonable and logical action, then, is to widen the specification to accommodate the increased margin of error. However, few clients are receptive to the widening specifications. This situation brings back the "garbage in equals garbage out" rule.

The outlined standard error calculation provides the minimum error based solely on the heterogeneity of the material. All other errors add to this minimum error. Pierre Gy (who sadly died on November 5, 2015) listed six other errors aside from this fundamental sampling error (FSE). These include the "nugget effect" from geo statistics — it is equivalent to the undeterminable x_{100}. It also includes delimitation errors, where certain particles have lowered chances of entering the measurement zone — obviously each particle needs an equal chance of being sampled for statistical validity. There is also the analytical error — normally at least two orders of magnitude lower than the FSE. And there are others that will not be discussed here, except to remind you of segregation, where a representative sample simply isn't possible unless the whole sample mass is taken. This is the classic "Brazil nut effect,"

also known as granular convection. This occurs when granular material of varying sizes shows patterns of movement similar to fluid convection when subject to vibration or shaking, and the largest particles end up on the surface. An example is a container of mixed nuts, where the Brazil nuts (usually the largest sized) end up on top.

Sample collection

The classic question comes down to how to take a sample containing the minimum mass required. Even with careful sample division, the minimum number of particles must be met at the particular point in the distribution. Otherwise, we cannot achieve low sample-to-sample variation. There are two golden rules of sampling expounded in Refs. 1 and 3.

- All samples should be taken when the stream is in motion, rather than stationary
- The objective should be to sample the entire stream for a given period of time, rather than only a portion of the stream for a long time

Allen has provided a classic table in all his editions of his "Particle Size Measurement" books, and it is recreated here in Table 4.

Only with the spinning riffler technique do we get below 1% standard deviation between repeated samples. Indeed, this principle was known in early mining days where wooden buckets and barrels were employed (Figure 3).

The principle of these rotary dividers is also seen in larger-scale variants that retain classic good sampling practice, such as the Vezin sampler and the Burt sampler for slurries and suspensions.

In the slit-type devices favored by the coal industry among others and exemplified in a number of ASTM Committee D-5 standards are the Jones riffler and its variants (Figure 4).

All the above considerations can be obviated if a sample segregates. We may all be familiar with the phrase "The contents may have settled during transit" and the bottom of the potato chip bag containing fragments rather than whole chips. These are simple examples of segregation where one part of the sample is markedly different from another even though each could contain far more than the minimum required sample mass. Early mining illustrations show this segregation and a nice sampler from Jenike and Johanson also illustrates the so-called "Christmas tree effect" (Figures 5 and 6).

In these cases, the only route is to take the entire material, while moving (dropping under gravity from a conveyer belt) and extract a portion of the whole flowing stream for a period of time. This is why samples from mining operations were substantial fractions of railway wagons or large numbers of alternate shovels-full.

Concluding remarks

To summarize, the analytical laboratory can only be as good as the submitted sample. The origin and transport of the material to the laboratory is crucial in understanding potential sampling errors that may arise. To finish with another quote from the realm of early computing pioneer Charles Babbage:

"On two occasions, I have been asked, 'Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answers come out?' In one case a member of the Upper, and in the other a member of the Lower House put this question. I am not able rightly to apprehend the kind of confusion of ideas that could provoke such a question" [*8*]. ■

Edited by Scott Jenkins

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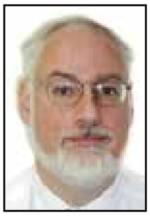
Author



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Part 2

Preventing Flow Stoppages in Powder Handling Processes

Predicting powder flow behavior is important to successful solids-handling processes. Provided here is a review of shear-cell testing and how the technique can be used to predict arching, ratholing and other behaviors

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IN BRIEF

The phrases "failure to discharge" and "erratic flow in the hopper" are sometimes heard from frustrated production-floor workers when powder processes start to misbehave. Taking corrective action for these types of problems may involve shutting down the process to investigate the root cause. Ideally, processors would identify suspect powders prior to processing, thereby avoiding costly downtime. Traditional methods for predicting flow behavior — flow cup, angle of repose and tap tests — are giving way to shear-cell testing, which measures inter-particle sliding friction, as well as powder-to-hopper wall interfacial friction. This article explains the science behind shear-cell measurements. Predictions for density-compaction ratio, potential arching dimension or rathole diameter, and design requirements for hopper half angle to achieve mass flow are reviewed.

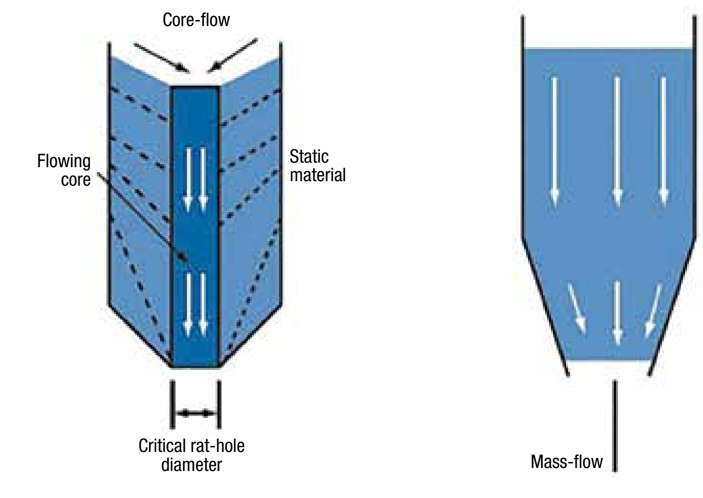


FIGURE 1. The diagram shows core flow (left) and mass flow (right) patterns

Types of powder flow behavior

Figure 1 illustrates two common flow types. "Core flow" is the default discharge pattern experienced on the production floor. When the feed bin is filled with powder, the material's behavior can be characterized as "last-in, first-out." Powder flows from the top of the vessel downward through a vertical channel above the outlet. Material around the walls remains static until the fill level reduces to expose stationary particles, which now become the top free surface. If powder is refilled into the hopper regularly, material near the bottom of the vessel may remain in place for long periods of time until the vessel drains to empty. Potential dangers include compaction of the stationary powder and potential caking or bridging in the hopper outlet. Powder that remains stationary for too long a time risks spoilage or other problems related to aging material.

Many companies in the chemical process industries (CPI) experience flow problems and core flow behavior due to the cohesive nature of powders, such as carbon black and calcium carbonate.

Mass flow is the preferred discharge pattern. The flow behavior in this case can be

FIGURE 2. The components of a shear cell tester include the vane lid (left), wall friction lid (middle) and the trough (right)

characterized as "first-in, first-out." In mass flow mode, powder throughout the bin is in motion simultaneously, including particles in close proximity to the wall. One important advantage of mass flow is that blended powders undergoing mass flow in a hopper generally maintain their compositions, whereas blended powders tend to segregate with core flow.

Time consolidation

Consolidation of powders can occur when powders fill and occupy a vessel. Powders may increase their internal strength (also known as "failure strength") from the initial moment they fill the bin. The weight of powder pushes down on particles below due to gravity, so powder at the bottom of the vessel experiences the highest compaction stress. Air gradually squeezes out from empty spaces between particles. Consolidation takes place as particles move closer together. Increases in powder strength depend on the amount of time the powder remains stationary and undisturbed. Like a packed snowball, the powder can reach a state where it cakes and resists movement when discharge out the hopper finally commences.

Powder density

Measuring the compressibility of a powder is one experimental way to predict flow behavior. The greater the extent that a powder compresses together, the greater its powder strength. One possible consequence of this higher powder strength is that powder flow becomes increasingly difficult.

The tap test is an established method for measuring compressibility of powders. In a tap test, an empty cylinder of fixed volume is filled to the brim with the powder. The cylinder is tapped up and down a defined number of times (perhaps 100 or 150 repetitions). After the tapping, the reduced fill level of the powder is measured, then divided by the initial fill level to calculate the compressibility ratio. Tap tests can be accomplished relatively quickly, but they provide only two data points on a curve — namely the loose fill density and the compacted density after a defined number of taps. The tap test may be run several times to determine the steady state for maximum compaction after the defined number of taps.

A rule of thumb is that powders that compress more than 35% from the loose-fill condition in the tap test may exhibit flow behavior problems in powder handling operations. An observation of 50% compressibility is a sure indication that processing will have challenges related to powder flow, especially if there is any downtime after the powder is placed in the bin or hopper.

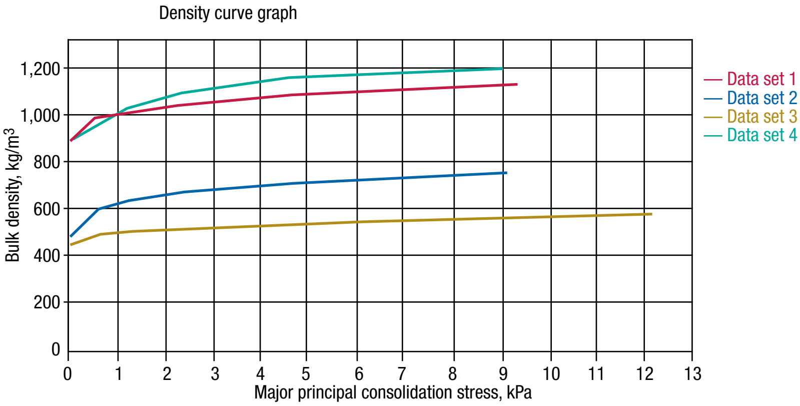


FIGURE 3: In a density curve, the *x*-axis shows the consolidating stress, and the *y*-axis shows bulk density

Powder mechanics and obstructions

Fundamental to predicting powder flow is analyzing inter-particle friction. Resistance to movement in powder processing is due to sliding friction between particles, as well as interfacial friction between the powder and the hopper surface.

Three types of obstructions may occur to prevent discharge from a bin. The "mechanical arch" involves large particles interlocking with each other and blocking the outlet. A "cohesive arch" occurs when powder at the bottom gains sufficient strength due to consolidating stresses that it solidifies and bridges the outlet. "Rathole" formation takes place when the powder in a vertical core above the outlet discharges and powder throughout the rest of the vessel remains static.

Segregation is a problem that may result during blockages. Particles of differing shapes and sizes separate across the cross-section of a vessel or hopper. One typical pattern of segregation is an increase in fine (smaller) particles near the central axis of the vessel and a greater concentration of coarse (larger) particles near the outer walls.

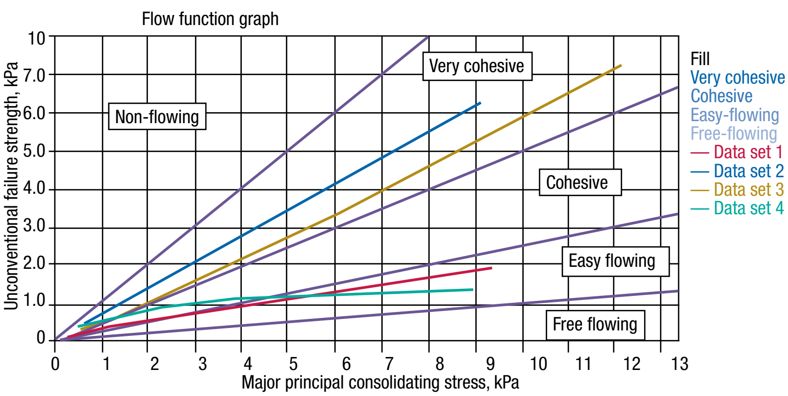
Annular shear cell

Over 50 years ago, the minerals industry devised a technique to quantify sliding friction behavior during powder discharge from a bin by measuring aggregate shear forces between particles in a controlled sample. This initial experimental work led to the development of the "annular shear cell," a chamber that holds the powder sample, allows it to be consolidated, and then exposes it to uniform shearing forces in order to measure the yield stress necessary for relative movement. Figure 2 shows typical shear-cell components.

The annular cell in which the powder is placed has a well-defined volume. Various chamber sizes are available to accommodate whatever amount of powder is available for testing. The shear cell is then placed onto the "powder flow tester" instrument. A lid affixed to the compression plate on the instrument descends onto the sample and consolidates the powder to a defined stress value. Reduction in the sample volume as powder particles push together is automatically measured by the instrument. This procedure for consolidating the powder using a defined stress is repeated multiple times to verify that the powder has achieved "critical consolidation," meaning that particles have reached an equilibrium condition with relative spacing.

There are two types of lids used on the instrument, one to measure interparticle friction (vane lid), the other to measure wall friction, which simulates powder sliding against the hopper wall prior to discharge (wall friction lid). The test procedure, regardless of lid type, involves compressing the powder at increasingly higher stress levels to evaluate change in powder strength. At each consolidating stress level, the trough rotates slightly on the instrument turntable and powder friction is measured.

FIGURE 4: Powder strength data at each consolidating stress are plotted to create a flow function graph



Density measurement

As the annular shear-cell test progresses, the reduction in sample volume is measured and the powder bulk density is calculated. Figure 3 shows graphical data for different powders from the density test. The *x*-axis is the consolidating stress, in units of kiloPascals (kPa) and the *y*-axis is the bulk density in kilograms per cubic meter. Software used with powder flow instruments typically has flexibility with regard to the choice of scientific units when reporting data. The loose-fill density at the beginning of the test is shown by the leftmost point on the graph, representing the powder condition when it is first poured into the bin. Bulk density values increase as the test progresses and normally approach an asymptotic value as consolida-

tion of the powder reaches a maximum. The amount of consolidation between the loose-fill condition and the maximum density is expressed as a compressibility ratio. This numerical value is comparable to industry standard calculations from the tap test described previously, namely the Carr index and the Hausner ratio.

Flow function test

The vane lid is used to perform the flow function test. Powder strength is measured as "yield stress" by shearing particles trapped in the lid pockets against particles in the shear cell. Powder strength data at each consolidating stress are plotted on the graph in Figure 4 to produce a graph called a "flow function." The solids-handling industry has established regions of flow behavior, as indicated in the figure, ranging from "free-flowing," along the x-axis, to "non-flowing," along the y-axis. Powders that are likely to exhibit flow difficulty in solids-handling processes are typically those that fall into the "cohesive" or "very cohesive" categories. These powders would be primary candidates for flow-aid additives to reduce internal friction between particles.

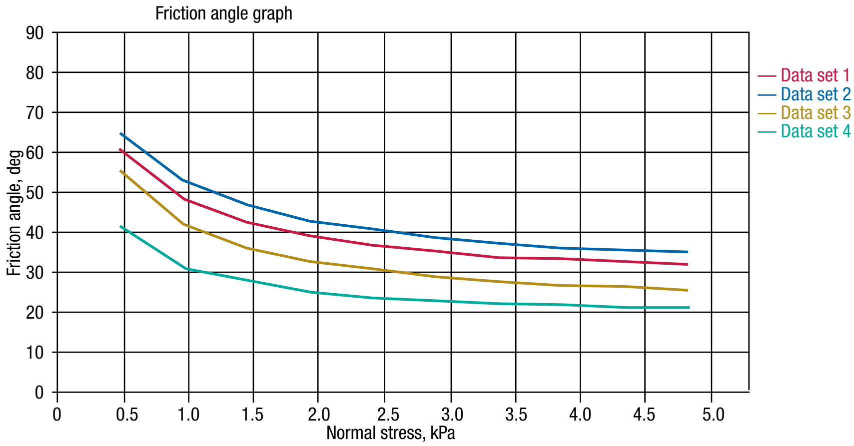


FIGURE 5: Different powders will show different wall-friction behaviors

Wall-friction test

The wall friction lid is used for this test. The material of construction used for the lid surface is based on actual hopper design — instrument vendors provide a range of offerings for different grades

of steel and plastic routinely used in hopper construction. The test method for wall friction measures interfacial friction between the powder sample and hopper wall material at increasing consolidation stresses. Figure 5 shows a graph of wall friction behavior for various powders. Wall friction angles above 30 deg are considered high, and may lead to flow difficulty in powders.

Many processors in solids-handling facilities are limited to the use of equipment that is already in place . . . Two possible alternative options for finding solutions to flow problems could include changes in hopper wall material or an increase in cleaning frequency for the hopper surface.

One important point to note about hopper walls is that powder buildup may occur over time during processing. This can be simulated in the wall friction test by conditioning the lid accordingly and measuring the change in yield stress between the lid and powder sample. The general observation is an upward shift in the curves shown in Figure 5, which means greater resistance as powder slides down the hopper wall during discharge.

Arching dimension and ratholes

Critical arching dimension is a conservative calculation of powder in mass flow that describes what conditions are necessary to build a stable bridge over the hopper outlet, thereby restricting discharge. The method for making this determination involves identifying the "critical consolidating stress." Software provided by instrument vendors will establish a hypothetical line, referred to as a "flow factor," which intersects the flow function. The point of intersection is known as the "critical consolidation stress." Given this value, it is possible to perform calculations to determine the arching dimension and rathole diameter.

Hopper half angle for mass flow

By integrating data from both the flow function and wall friction tests, it is possible to calculate a value for the hopper half angle that will enable mass flow behavior to take place. Software provided by instrument vendors automatically performs this calculation.

Practical design considerations

Some powders require such steep slopes for hopper half angle (greater than 80 deg relative to horizontal) that equipment designs capable of meeting the requirement are not practical. These designs would result in discharge hoppers at the bottom of the bin that could be taller than the bin itself.

Many processors at solids-handling facilities are limited to the use of equipment that is already in place, and cannot make design changes to replace equipment. Two possible alternative options for finding solutions to flow problems could include changes in hopper wall material or an increase in cleaning frequency for the hopper surface.

Another approach for improving flowability is to incorporate additives into the powder formulation. Similarly, mechanical-assist devices, such as vibration and aeration, are other possible considerations. Trade-offs must be evaluated between the cost of these interventions versus the consequences of the lost processing time due to flow stoppages related to equipment downtime or poor product that requires rework.

The objective is to know before each process run what difficulties lie ahead. The flow function test has been streamlined to under 20 minutes for five consolidation-stress setpoints and under 12 minutes if two consolidation-stress setpoints are practical for providing a quick go/no-go assessment. This test gives a useful indicator for potential problems and puts the processor in a better position to respond in advance, thereby avoiding unexpected stoppages. ■

Edited by Scott Jenkins

Editor's note: For more information on shear-cell testing, see *Chem. Eng.*, April 2016, pp. 50–59, and *Chem. Eng.*, January 2016, pp. 58–63.

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Methods to Achieve Sustainable CIP

A clean-in-place (CIP) system is among the largest users of consumables at a hygienic processing plant. Presented here are tips for reducing the consumption of water, chemicals and time in CIP operations

Tyler Previs and Len Roche
Seiberling, a Haskell Company

IN BRIEF

In many industries there is a burgeoning awareness and pursuit for financially justifiable resource conservation. The cleaning routines that make sanitary processing possible are among the largest users of consumables in a facility. Clean-in-place (CIP) is the automated approach of cleaning process equipment with minimal manual intervention. It is one of the most important aspects of hygienic production; however, many plants ignore CIP procedures unless issues arise. Due to this oversight, opportunities to make CIP more sustainable are lost. Optimized CIP programs not only ensure product integrity, but also provide valuable savings through the conservation of water, energy, chemicals and available production time. There are many process design philosophies, mechanical components and automation solutions that make this not only feasible, but cost effective.

Benefits of practicing CIP

CIP is practiced in industries where hygienic production is necessary to produce product that is pure and safe to consume or use. Historically, cleaning of hygienic processes was achieved by hand through very labor-intensive procedures for which it was difficult to ensure repeatability. With the advent of CIP, available production times increased as plant-wide shutdowns for disassembly and cleaning were no longer required. Today, individual processing units can be isolated and cleaned independently without impact to production in other areas, allowing for continuous 24-hour production. Worker safety has improved by reducing high-risk activities, such as confined space entry and disassembly of pipes that could be pressurized or contain cleaning chemicals. The widespread acceptance of CIP in the food and beverage industries, along with advancements in implementation practices, has led to further acceptance into other industries. The pharmaceutical and biotechnology industry standards rely on these repeatable processes that can be validated. The design and prescribed CIP regimen of a given process can be refined to minimize the use of consumables without degrading total effectiveness.

Example of a typical CIP application

To understand where potential savings exist, it is necessary to understand a typi-

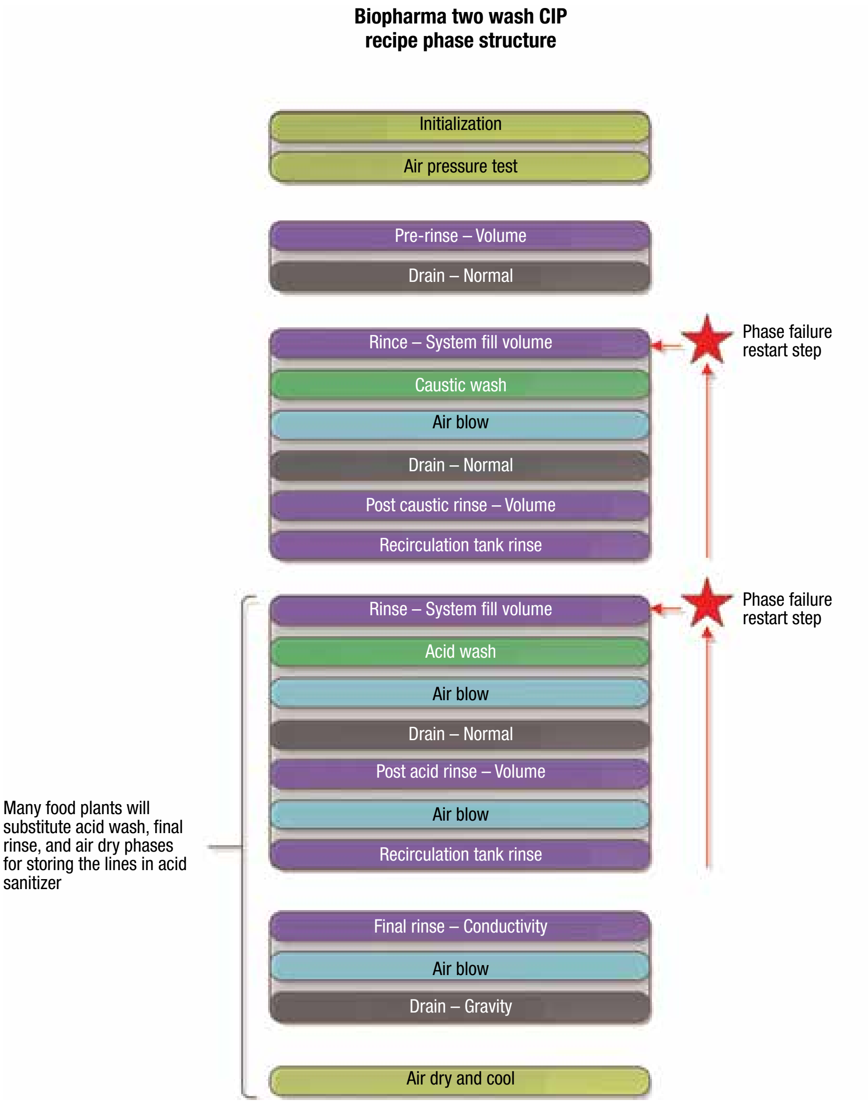

FIGURE 1. Shown here is a typical two-wash CIP recipe phase structure for a biopharmaceutical plant

cal CIP cleaning approach (Figure 1). Cleaning recipes do vary by industry, but are founded on the same principles. CIP relies on time, temperature, chemical action and mechanical force. In general, water-based solutions are used to remove residual product from the process equipment. After initial water rinses, a heated dilute caustic solution is circulated, followed by an acid solution and a final rinse. Caustic is the primary cleaner and breaks down proteins and fats. Acid or acid sanitizers neutralize residual caustic and prevent mineral buildup on the equipment, improve drying, and can create a surface condition that inhibits bacterial growth. Acid washes are commonly substituted in food plants with the practice of storing process lines in sanitizer.

For tanks and equipment with large internal cavities, static spray balls supply cleaning solution to the top of the tanks, resulting in a turbulent sheeting action down the sidewalls. Piping with in-line components, such as pumps, valves and instrumentation, are cleaned at a minimum velocity to ensure fully flooded lines, which guarantees full chemical contact and maintains a suspension of settled solids. High-pressure dynamic spray devices remove viscous product from vessels. When selecting these devices, the supply pressure requirements are often much higher, the rotation of the spray device may need to be tracked via proximity switch, and the process lines supplying the vessel still must clean at the proper flowrate, which may exceed that of the tank spray device requirement.

There are multiple hardware advances to improve cleaning effectiveness and reduce waste. Many of these reduce CIP dead legs in length (Figure 2). A dead leg is defined as the length of a branch (L) divided by the internal diameter (D), or L/D. The industry standard for CIP cleanable connections is less than $2L/D$. Empirical tests confirm that the shorter the L/D, the quicker the dead leg rinses. Branches, such as instrument tees, should be installed in the horizontal to prevent trapped air from compromising solution contacting all surfaces. It is important that the system is designed with cleaning in mind from the start for CIP to work effectively.

Recent developments in technology and industry practices are being leveraged to drive success in the area of sustainability. Production facilities focusing on conservation have effectively integrated CIP via new mechanical and automation solutions to foster more economical practices.

Achieving sustainable CIP

The most impactful approach to achieving sustainable CIP is by integrating the practices early on in the design of a new plant or expansion.

Location and piping size. Considerations, such as locating the CIP units central to the largest users, will minimize dedicated CIP piping. This reduces hold-up volume in the piping, which is filled several times during each cleaning cycle. The excess volume is a function of CIP design, but has no bearing on its effectiveness. Essentially, this physical volume is a fixed cost of performing CIP, regardless of the level of residual soil in the equipment being cleaned.

For systems that are cleaned multiple times a day, such as product tankers, a CIP unit in close proximity can save recurring costs. For example, in a milk plant that receives 54 milk tankers to sustain a 325,000-gallon daily production, the CIP units were grouped in one area near the utilities rather than near the

process loads. The tanker receiving-bay CIP unit was 130 ft away and estimated to consume 6.2 million gal/yr of water. By moving CIP units within 40 ft of the receiving area, the line lengths were shortened by more than half the original length, with water consumption reduced to 3.3 million gal/yr. Additionally, 11,000 gal of high-strength acid and caustic chemical usage was conserved. The reduction in water, energy, chemicals and waste stream effluent to be treated resulted in a savings of $125,000 per year. Considering the lifespan of facilities, the careful placement of CIP systems close to users can result in savings that more than offset the initial capital cost.

Another important consideration in a new facility is to take the extra time to properly size the CIP distribution piping and associated supply and return pumps to design a system that is functional, yet not oversized for the cleaning demands. In the previous study, 1.2 million gal/yr of water and 10,000 gal/yr of high-strength chemical were estimated to be saved by downsizing the piping from a 3-in.-dia. line to a 2.5-in.-dia. line.

Product recovery and instrument optimized rinses. In the case of existing plants, where resizing piping and moving or adding additional CIP units may be impractical, there are still many opportunities to improve CIP sustainability. Product recovery options, such as air blows, water pushes and product recovery systems, can help plants reclaim a majority of the product remaining in the lines. When paired with CIP, less water is used in the first rinse to flush the process piping. This two-fold effect provides plants with more usable product for sale and a reduced water usage.

Product recovery water pushes can be sourced from a CIP unit or designed functionality in valve arrays. Turbidity sensors placed at the end of transfer lines or at the CIP return (CIPR) measure the rinse water optical density (Figures 3 and 4). The commissioned change in opacity will determine when the product-water interface has passed. Due to turbulence-induced mixing as a function of distance, this interface becomes elongated and can be thought of in three distinct regions: product, product-water mixture, and water (Figure 3, bottom). For each region, a different condition is programmed and flow diverted accordingly. When product is encountered by the turbidity sensor, the process line remains open and the residual product is recovered with the rest of the

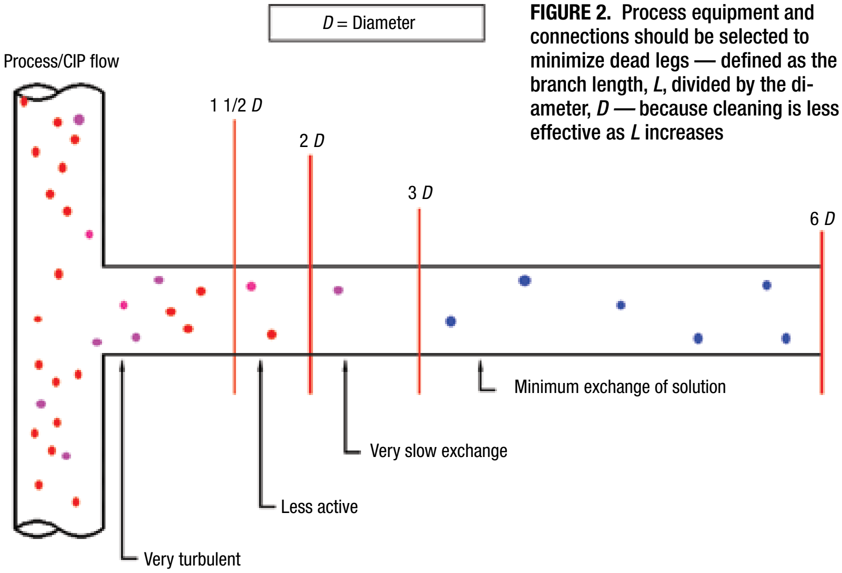

FIGURE 2. Process equipment and connections should be selected to minimize dead legs — defined as the branch length, *L*, divided by the diameter, *D* — because cleaning is less effective as *L* increases

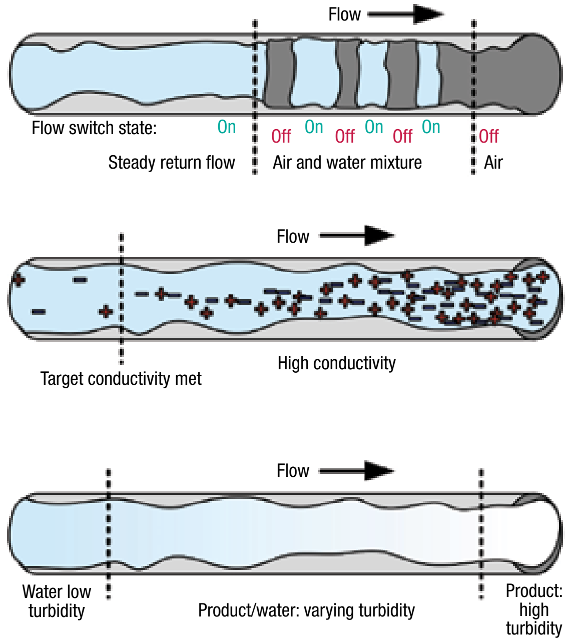

FIGURE 3. Return flow switches, conductivity probes and turbidity sensors are used to efficiently transition CIP operations

batch transfer. For the water-product mixture, flow can be diverted to an "Ag system" for storage and distribution as livestock feed. Because the diluted product still has nutritional value, it can be sold for profit to farms, reducing the facility's water-treatment costs. Flow is diverted to the drain when water is detected and the CIP unit moves to the next step in the CIP program.

Following a chemical wash, an analytical sensor located at the CIPR measures conductivity of the rinse solution. The rinse phase concludes once the conductivity drops below the set threshold for a duration. The sufficient amount of rinsing is performed for each circuit without a fixed excess volume built in for robustness.

In process lines where the risk of cross-contamination between allergens is nonexistent, a reuse CIP system may be used (Figure 4, top). Unlike in single-use CIP (Figure 4, bottom), where cleaning solutions are made up once, used, and disposed, a reuse CIP system recycles them as a pre-rinse for future cleaning. The chemical recapture at the reuse CIP skid is akin to the process water push approach.

With the use of both turbidity and conductivity sensors (Figure 3), CIP systems can now be tailored to specific products and process lines, ensuring excess water is not flushed down the drain after piping has been rinsed. Return flow switches are also installed at times to confirm that water has been received back to the CIP skid. Performing a return flow check early on in the cleaning cycle for system integrity is desirable before investing more time before a secondary alarm results in the failure. Periodically confirming the calibration of the sensors will improve their efficacy.

Process modeling. Generating schedules from process models with system user participation to determine realistic requirements and avoid bottlenecks is paramount. Equipment utilization can be managed more efficiently when activities are modeled in concert. The more constraints included and degree of granularity pursued, the more valuable the model will prove to be. Benefits yielded from the exercise include the ability to anticipate future capital projects, properly staff and negotiate equipment conflicts.

Process models can also include pictorial representations (Figure 5) of automated operations on piping and instrumentation diagrams or schematics known as color code drawings. Generating color codes can visually represent complex processes and allow streamlining of automation sequencing. The drawings can be referenced to clearly communicate between process and automation groups while also facilitating commissioning and training.

Disposable equipment can eliminate cleaning from the equation. Single-use equipment, as used in the biotech industry, eliminates the need for cleaning and steaming. Using pre-sterilized bag vessels and filters can increase overall equipment effectiveness. When considering a new facility, the cost of bags can have a better return on investment than fixed tanks with CIP, steam in place (SIP), water, waste, chemicals and other utilities. The avoided costs of cleaning validation and commissioning time are added major benefits. On an existing facility, implement disposables judiciously to increase production without adding equipment. Also, the process space can be more dynamic, more easily accommodating future products of smaller batches with unique unit operation configurations. A hybridized process design can utilize the benefits of both approaches while remaining scalable.

Connectors to reduce vessel dead legs. Vessels can have internal dead legs if attention is not put into initial equipment designs. Sidewall and tank top connections are traditionally 2-in. long clamp connections, which can be difficult to reach with a spray device. Short, machined outlet ferrules reduce the dead leg to generally less than 0.5*L*/*D*. Recessed connections can prove challenging during coverage testing. Tank head ports should be accessibly grouped in a circular arrangement around spray devices to allow for more favorable spray angles. Otherwise, custom spray patterns are usually required, as well as increased flowrates, to ensure solution reliably makes contact with all internal surfaces. The water sheeting on the sidewall of a vessel during CIP is usually sufficient to wet the short outlet ferrule connection surfaces.

Self-priming liquid-ring pumps improve CIP robustness. The CIP return (CIPR) path portion of a circuit is prone to have hydraulic issues, as vessels are kept as empty as possible during cleaning. A small puddle in a non-vented vessel will trap positive pressure in the tank and reduce more water buildup. The water pressure properties are equivalent to a column of water stuffing the CIPR pump. Less water in the vessel reduces overall resources expended for the CIP. Occasionally, a mixture of air will be present in the outlet line

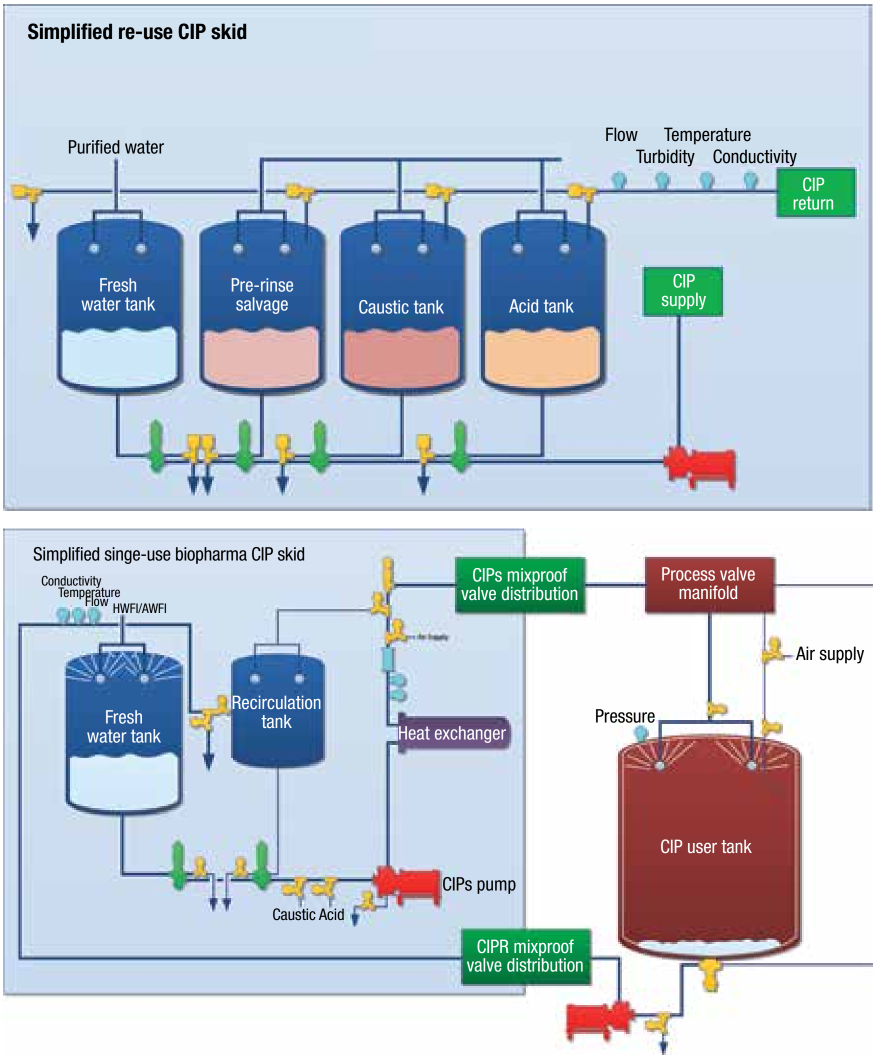

FIGURE 4. Shown here are two examples of CIP circuits with associated hardware and instrumentation. Such circuits can be designed to reuse cleaning solutions (top) or for single-use CIP (bottom)

from a vessel, causing some centrifugal pumps to lose pumping capacity from cyclical air binding.

A liquid-ring pump facilitates this by being capable of pumping air and water. Liquid-ring pumps usually have a higher net positive suction head required (NPSHr) than conventional centrifugal pumps. This exacerbates the fact that they can compromise their upstream stuffing conditions by generating a strong enough vacuum in unvented vessels to the point where they no longer pump. This concern is especially present when pumping hot solutions where the vapor pressure of the liquid approaches boiling. The vessel should be vented or make-up air should be added to avoid net positive suction head available (NPSHa) issues at the return pump.

Pre-rinses targeted at the dirtiest piping first. During CIP, the process valves cycle to ensure solution is directed down each path. Most programs have a single flow sequence that includes all targeted pathways. There are many ways to structure the valve sequencing to reduce consumption. One quick method is to deploy targeted pre-rinses or reduced chemical concentration washes to the bulk soil load paths to drive residual product out of the system. Isolating the high-soil paths will prevent the spread of soils on additional system surface areas and alleviate foaming issues.

Another rinse approach for less troublesome soil loads consists of designing the longest serpentine pathways without device sequencing active. Parallel paths should be

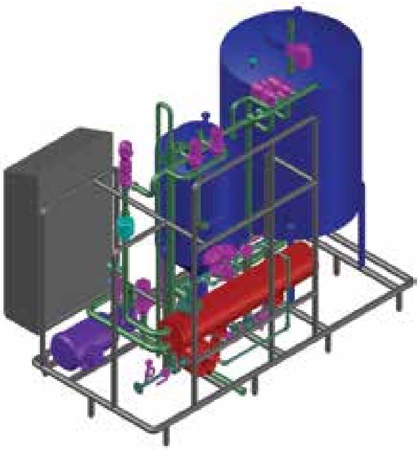

FIGURE 5. Shown here is a 3-D model of a single-use clean-in-place (CIP) skid with a tulip recirculation tank

flushed independently and sequentially down the main route to avoid entraining soil into the path of rinses. Each path timer should be set to clear the entire ancillary route per device sequence iteration. Flow-split, pressure-drop calculations should be performed for unavoidable parallel paths, such as at valve array loops, to ensure sufficient velocity is present. The various step timers can be confirmed in the field by measuring the pipe temperature between phases with differing setpoints. A similar philosophy should be carried out for large filter housings. When cleaning across larger filter housings that support multiple elements, sequence time should be allocated to allow for evacuating accumulated volume while avoiding multi-directional flow. Outlining a cleaning program with coupled rinses and drains will promote successful cleaning for non-ideal piping configurations.

When drain valves or other system boundaries are pulsed open to receive cleaning solution, the exposure time should be confirmed in the field. Significant command execution delays may be inherent in the control system, resulting in executed time being exorbitantly long. Excessive solution loss may be incurred, which can compromise a stabilized circulated wash.

The wide functionality of pressurized air sources at CIP skids. Pressurized filtered air from the CIP skid can be used to air blow the supply lines clear of chemical solution to facilitate rinsing or draining. The air pressure should be regulated adequately to overcome the water column backpressure of the tallest line while also considering the pressure rating of safety devices at the user equipment.

The puddle size in a vessel during CIP should be minimized. During phases where temperature increases, pressure will accumulate in unvented vessels, which will aid in pushing out the water. Sometimes, at the start of a cold rinse phase, a vacuum may develop, causing water pooling to the point of compromising return flow. Injecting air into the CIP supply line or applying local top pressure while operating under deadband control will make for a much more robust, hydraulically balanced system regardless of starting conditions. Supply stream air injection can also dampen hydraulic shock during valve sequencing.

The same air source can be used to perform pre-CIP air pressure checks on the supply paths where manual intervention exists. With simplified logic, any detected leaks can prevent otherwise schedule-impacting delays.

Avoid unnecessary wait delays in programming logic and tune parameters right the first time. Streamlining CIP skid logic can also provide time savings. Executing multiple operations simultaneously, such as filling a water tank to prepare for an upcoming phase while performing a different operation, can remove fixed wait times. Predicting water tank fill levels depending upon phase parameters can also reduce the amount of unused water that is sent to drain. Electing to validate unique cleaning parameters for like equipment, rather than a family approach, will be beneficial in the long run but may extend startup times.

Depending upon the heat exchanger, there can be substantial latent heating or cooling from a previous phase, which results in a delay to setpoint. Water is sometimes wasted during the wait until reaching the forward flow conditions.

In the event of the program failing for an alarm condition, the entire cleaning operation is typically repeated. One alternative is allowing the option to repeat the phase that experienced the failure. An equipment cleanup failure logic phase can also be initiated to restore the circuit to a rinsed, drained safe state if the circuit experienced a more critical alarm.

In some industries, there is great cost associated with revalidating parameters even if they optimize an existing process. Therefore, it is imperative to perform due diligence before the commissioning effort begins. Coupon sampling cleaning studies using the same materials of construction and cleaning agents prior to process implementation can avoid validating a system that relies heavily on excessive chemical concentrations as a panacea. Also, ensuring chemicals are adequately mixed will avoid the need to overdose to avoid alarms due to dips in conductivity.

Blockbody and mixproof valves reduce system volume and piping footprint. Blockbody zerostatic diaphragm valves can eliminate dead legs to facilitate rinsing, as well as system fill volume, while saving high-value product. Corner-configuration blockbody ported valves can also reduce stack-up heights and lower return pump inlet lines, in turn reducing vessel puddle size by improved

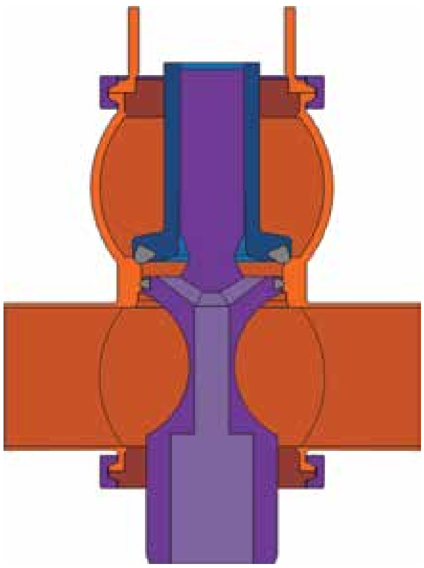

FIGURE 6. Mixproof valves combine the operation of two block valves and a bleed valve into a single unit, thereby decoupling simultaneous operations while reducing floorspace footprint

NPSHa. Occupied installation space can be conserved by consolidating the valve bodies.

Mixproof valves (Figure 6) reduce floorspace footprint and safely decouple simultaneous operations. Their design simplifies the use of two block valves and a bleed valve into a single piece of equipment. Increased pressure loss from passing through particular port combinations and reduced holding pressures should be accommodated in the design. The process flexibility granted by the valves eliminates delays from otherwise existing equipment conflicts. Prefabrication of mixproof valves as part of skidded valve arrays in shops can improve quality and simplify installation.

Decoupling transfer lines from tanks. A common transfer line can be cleaned more frequently than the supporting vessels if their cleaning paths are decoupled. A batch operation can be executed almost continuously by employing this separation scheme. A rolling simultaneous clean, processing, and dirty status can occur between vessels of the same family. The pseudo-continuous operation permits longer production windows. Vessels do not need to wait for the conclusion of production in an area prior to conducting CIP.

Added transfer flexibility comes at the cost of additional validation and programming. One should be cautious with overcommitting to transfer flexibility. The number of cleaning circuits can grow factorially to accommodate variable manufacturing transfer options. Operations can be restricted to select paths, or the combined circuits may be broken up into smaller pieces to fit the production schedule. A commission and validate "as needed" philosophy can be implemented to delay commissioning all variations at one time while avoiding future construction shutdowns.

Post-CIP air drying to extend clean hold times. At the conclusion of most biotech CIP programs, the equipment is allowed to drain completely, but water droplets will cling to the surfaces from surface tension. The warm damp air in the system boundary will eventually cool and condense long after the drain phase. Stagnant water within a clean system should be avoided as it provides the environment for bioburden to appear. Food plants will store lines in sanitizer to create a bacteriostatic environment. Another method in practice today to reduce residual water post-CIP to keep bioburden to a minimum and extend equipment clean hold timers is air drying.

Air drying can be achieved by iteratively pressurizing process vessels with dry air and venting. Pressurization is a heating process and causes more water to evaporate into the air. Upon depressurizing, the vapor will condense in suspension, having crossed the dewpoint via adiabatic

cooling and evacuate from the vessel to the drain point. The cyclical pressurization-dilution method for pressure-rated vessels is more effective than passive open-path drying with clean air.

Positive pressure on the vessel should be maintained to avoid vacuum formation during the cooldown, which can pull contaminants into the system boundary. When venting to drains, it is important to not over-pressurize waste headers, which can impact adjacent simultaneous operations. Larger vessels can take in excess of one hour to air dry. Therefore, using a local dedicated air source will allow for the CIP unit to be released for other users and free up utilization.

Planning should be done for point-of-use air filtration for user local sources and cleaning boundaries. The retained heat in a vessel is the majority driver of the drying due to its thermal mass. Drying piping is more challenging, as it cools more quickly. Design considerations should be made to facilitate drying, such as avoiding parallel paths, confirming slopes, and ensuring venting locations are designated for circuit boundaries. The decrease in pooling water can safely validate an increase in clean hold times, reducing the total number of CIPs that must be performed.

Actualizing CIP sustainability

Regulatory guidelines, validation and commissioning requirements vary significantly by industry. Even with this considered, the discussed concepts can in part be adopted to provide value. Each action item individually will not provide immediate notable change, but embracing a sustainable CIP philosophy from the start of a project will pay significant dividends for years to come. A holistic CIP integration design approach is necessary to realize the opportunities that exist for reducing sanitary process consumables. Employing new vetted mechanical equipment, current best-design practices and streamlined automation will align a project for success. ■

Edited by Gerald Ondrey

Authors

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Higher process reliability with Austrian technology

Increasing competition and ever more stringent quality requirements are placing high demands on the global chemical industry. The Berndorf Band Group is committed to optimising chemical processes by means of innovative technologies and to ensure long-term success.

Berndorf Band is a long-established firm with over 90 years of experience in belt production and developing plant to meet the specific requirements of its customers. Only manufacturers with efficient, high-quality production facilities will be able to remain competitive in the future. Therefore, optimising the effectiveness of existing production lines to ensure they continue to operate without fault is crucial. Due to its comprehensive know-how in this area, international chemical industry manufacturers rely on the Berndorf Band Group's expertise and innovations.

Conveyor belt precision

Precise belt tracking is particularly important in chemicals production. The Berndorf Band Group's process belts stand out for their exceptional flatness, dimensional stability and flawless running characteristics – the results of intensive research and development. Thanks to high-quality processing of the material used – super duplex NICRO 85 – Berndorf belts also excel when it comes to corrosion resistance. The high-end material offers high static and dynamic strength as well as resistance against chloride-induced stress corrosion.

Efficient production with Berndorf steel belt casting and drying systems

Drawing on its extensive expertise, the Berndorf Band Group develops casters for precise, high-quality production of chemical products such as filter membranes. Specially manufactured upstream feeding systems and downstream processing components optimise manufacturing processes in terms of quality and productivity. The Berndorf Band Group also offers a virtual caster for complete process control, which can be used to perform a range of process optimisation calculations.

From initial consultation to after sales service

In order to fully satisfy the needs of its customers, in addition to innovative technology, the Berndorf Band Group offers a unique portfolio of worldwide services. Berndorf customers benefit from detailed consultations with experienced engineers, custom solutions and swift, expert repair services as well as steel belt and belt system maintenance. Belt systems can easily be adapted and upgraded to meet new production requirements.

Meet us at the Achema Fair: Booth C62 in Hall 5.1

www.berndorfband-group.com

The Best Pollution Control System for the Chemical Industry

Dürr Systems, Inc. is the ideal partner to solve exhaust emission issues in the chemical industry.

With over 4,000 installations worldwide and 45 years of experience in air abatement, **Dürr**'s capabilities, knowledge, and skills make resolving any pollution control situation simple.

The chemical industry has its own unique set of requirements and concerns when it comes to air emissions control. Dürr has three products that are ideal for the industry's specific conditions; the Ecopure RL, Ecopure SCR, and Ecopure VAR.

Taking the standard thermal oxidizer technology one step further, the Ecopure RL is a state-of-the-art rotary regenerative thermal oxidizer with one of the highest thermal efficiencies in the industry. Advantages of this proprietary system are a destruction efficiency of 99%+, low maintenance costs, the opportunity for customization taking into consideration the VOCs present, and short installation and commissioning time due to a pre-assembled concept.

The Ecopure VAR is a direct fired thermal oxidizer designed for destruction of waste gases and liquid hazardous residues with challenging calorific values. This system has been installed for a wide range of applications, has no restrictions in terms of pollutant type or quantity, is able to incinerate residual organic liquids even those forming acidifying gases, and has a number of heat recovery options. With years of proven success, the Ecopure VAR can handle difficult process with ease.

The Ecopure SCR serves to reduce nitrous oxides (NO_x) from flue gases or process gases when high NO_x conversion rates are required through selective catalytic reduction. This system can be used as a stand-alone application as well as in the flue gas cleaning stage after thermal oxidation. Additionally, it has a destruction/conversion rate of 99%+ all in one complete, turn-key system.

Dürr provides solutions that impress, integrating necessary equipment, including pretreatment and posttreatment components such as dust collection and acid scrubbers, to form a comprehensive air abatement system in one engineered process. Thanks to their years of experience, involvement in a broad range of industries, and global reach, Dürr provides the most efficient and effective pollution control systems for the chemical industry.

www.durr.com

80 GHz radar sensors for bulk solids and liquids on the rise

Measuring with radar technology provides for various benefits. Amongst others, its independency of the surrounding process conditions.

With their high frequency of 80 GHz, the **VEGAPULS 69** radar level sensor enables optimal focusing of the transmitted signal for bulk solids measurement. Especially in bunkers, containers and silos with numerous internal installations, this signal focusing helps to significantly reduce the number of interfering signals, i.e. false echoes, and makes reliable measurement possible in complex vessels.

Both the focusing and the high dynamics are ideal for all media that are difficult to measure due to their poor reflective properties: solids such as ash, dried sewage sludge or scrap glass shards. Despite their large measuring range of up to 120 m, VEGAPULS 69 radar level sensors, with their ±5 mm accuracy, also score points in smaller vessels.

When VEGAPULS 69 is supplemented by the display and adjustment module PLICSCOM, the measurement data can be called up and evaluated remotely at any time via Bluetooth. This is especially advantageous for sprawling, large-scale facilities or mobile applications. It allows you to keep an eye on all current process and diagnostic values on your smartphone or tablet, no matter the time of day, no matter where you are.

Its component for liquids, VEGAPULS 64 ensures precise filling levels even under difficult conditions with high accuracy and reliability. With the smallest antenna ever designed for a radar sensor, VEGAPULS 64 is unbeaten when it comes to measurement in compact storage or process vessels. For that reason it is recommended as a simple, universal solution for applications with challenging environs or difficult media.

www.vega.com

The VEGAPULS 69 is available in two versions. With a simple, light plastic antenna and a lens antenna integrated in a flange.

BEUMER supplies complete packaging lines for the chemical industry: Securely bagged and wrapped

The BEUMER GROUP supplies complete packaging lines which fulfill the complex requirements of manufacturers in the chemical industry. These include highly efficient filling, palletizing and packaging systems. Customers also get comprehensive support.

When the **BEUMER Group** implements a packaging line in the chemical industry, here is how it typically works: The bulk material passes from the silo along a conveyor section to the BEUMER fillpac FFS (form fill seal) system. This bagging machine is fitted with an integral, high-precision weigher which ensures the accuracy of the bag weights. High-performance palletizers from the BEUMER paletpac range then stack the bags quickly and accurately on pallets. Depending on the product requirements, the palletizers are fitted with a rotary clamp or double belt turning device which moves the filled bags into the required position. Even bags filled with granulate can be gently palletized, remaining dimensionally stable when stacked.

Customers use the high-performance packaging systems in the BEUMER stretch hood series to secure the load. For businesses in the chemical industry, efficient packaging of palletized goods is a crucial competitive factor. The film fits snugly over each product on the pallet, ensuring safe transport and good load stability. The film is highly stretchable and secures the material as it contracts. It is also very transparent and permits a clear view of the packaged goods. Barcodes on the products can be read without difficulty. When a cover film is placed over the top of the pallet, this solution also protects the goods against external influences from all six sides.

Customers get a complete solution from a single source and have a reliable point of contact for the whole job.

www.beumergroup.com

The BEUMER fillpac FFS: High throughput, availability and a compact design are key features of the system.

Hybrid Process for extraction of flavours and agents

EKATO UNIMIX and SOLIDMIX in combination

UNIMIX SRC 100

Extraction from natural sources face a rising demand.

EKATO SYTEMS offers a simple but powerful combination of its UNIMIX and its SOLIDMIX VPT:

Material Transfer's product line includes:

- UNIMIX SRC: efficient mixing, dissolving and pre-evaporation

Material Transfer's product line includes:

- SOLIDMIX VPT: efficient vacuum contact drying

Flavours can be obtained from natural sources by extraction. Active ingredients are dissolved in a solvent and purified. For EKATO SYSTEMS, a perfect mixing in combination with a vacuum contact dryer is a smart solution

Dissolving and pre-evaporation

The UNIMIX SRC blender allows the intense contact of products in different forms with the solvent. The high speed homogenizer in the UNIMIX SRC acts as both shear device and crusher.

Built as a heated vacuum and pressure vessel for high viscous products (featuring the EKATO PARAVISC impeller designed for best heat transfer), the SRC allows a pre-evaporation of the flavour loaded solvent.

The EKATO SOLIDMIX VPT heated vacuum contact dryer evaporates the solvent in the initial drying phase (pasty consistence) and later during the transition phase from paste-to-solid with a fine powder as a finished product.

Natural products vary in their texture. Product recipes require a flexible, multipurpose apparatus. The EKATO SYSTEMS equipment is a symbiosis of proven technology from both liquids mixing and solids drying. EKATO SYSTEMS offers support in the process development, including small scale and pilot testing in the EKATO SYSTEMS laboratory. If required, additional tasks such as filtration or thin film evaporation can be simulated. **www.ekato.com**

Safety Relays with Diagnostics and Line Fault Transparency

Safety Relays from Pepperl+Fuchs: Diagnostics, LFT, 1oo3 Architecture

Diagnostics, line fault transparency and 1oo3 architecture (one-out-of-three)—the new safety relays from **Pepperl+Fuchs** combine all of these features. The devices have a comprehensive test pulse immunity and are therefore compatible with commercially available digital output (DO) cards.

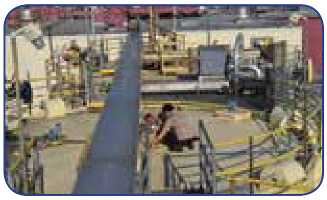
1oo3 architecture means that the switch contacts offer triple redundancy—three contacts arranged in series for DTS (de-energized-to-safe) applications and in parallel for ETS (energized-to-safe) applications. The benefit of this architecture is that the safety function of the device is retained even if up to two of the contacts fail.

During a switching operation, the diagnostics switches the three contacts of the 1oo3 architecture one after the other with a time delay. In ETS applications, three consecutive switching operations initially close all three relays of both contact groups cyclically. During the delay period, the device tests whether the first contact switches correctly, thereby detecting faulty contacts. In the DTS device, in contrast, two contacts close initially; the third contact is then tested and in turn closes after a time delay.

The new safety relays are line fault transparent and thereby facilitate signal circuit-specific detection of cable breaks or short circuits also on the field side without the need for additional wiring.

The single-channel devices are available for both DTS and ETS applications and are approved for ATEX/IECEx Zone 2 and UL. All devices are suitable for de-energized-to-safe function/energized-to-safe function for applications up to IEC61508 SIL 3; DTS devices can also be used for applications up to EN ISO 13849 PL e. The input circuits are identical for all devices from the entire portfolio. If a relay module on a DO card is successfully tested, all of the other variants of the safety relay are also compatible. **www.pepperl-fuchs.com**

Jenike & Johanson Engineering Services



Jenike & Johanson, Inc. is the world's leading technology company for bulk material handling, processing, and storage. They deliver engineered solutions to achieve reliable powder and bulk solids flow based on proven theories and decades of project experience. With their skilled, highly technical team of experts and industry-leading innovations, they have successfully delivered bulk material engineering solutions for more than 55 years.

Bulk materials and their flow properties are at the core of all Jenike & Johanson's work. Every project (7,500+ to date) is truly unique. Clients are offered maximum flexibility in selecting services required to meet their bulk material handling needs. Jenike & Johanson does not follow the "one size fits all" concept – which can be a dangerous pitfall in engineering. Decisions made during the feasibility and engineering stages of a project are critically important for its success. If bulk solids systems are not engineered from the outset to handle the unique characteristics of the materials, process start-up time can be significantly delayed and design capacity may never be reached.

The engineers at Jenike & Johanson are renowned experts in the field of bulk material engineering. They are frequent keynote speakers at major industry events, routinely deliver informative webinars and customized courses, and publish thoughtful technical articles in top industry journals and publications – all this in order to provide clients with the latest insight on cutting-edge methodologies which make the powder and bulk solids handling aspect of the business run seamlessly.

The chemicals industry provides the building blocks for companies manufacturing paints, pigments, coatings, adhesives, resins, consumer products, and foods. 75% of all chemicals are handled in bulk solid form during manufacturing. When feeding powders to reactors or conveying wet cake from a centrifuge to a dryer, poor material flow can result in throughput limitations, non-uniform product, or dust emissions/spillage. **www.jenike.com**

Ultra-High Efficiency Gas Absorption and Particulate Collection in a Space Saving Design

Now Achievable with Proprietary Bionomic Scrubber Technology

Overview

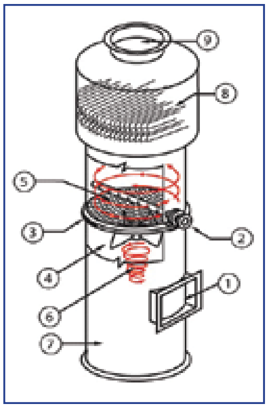
The patented RotaBed™ Fluidized Bed Scrubber represents a major breakthrough in ultra-high efficiency gas absorption and particulate collection in a space saving non-fouling design. RotaBed is the ideal technology for applications involving particulate laden gas streams or when handling high solids content or scale forming scrubbing liquids.

The key to the scrubber's superior performance is a unique swirl induced Coriolis grid that achieves much greater fluidized bed stability, resulting in more efficient gas mixing and transfer efficiency than less advanced designs. This unique approach to gas-liquid fluidization is accomplished without the need for marbles or plastic spheres that are prone to fouling or replacement due to wear. RotaBed's "packless", highly plug resistant grid cross section is up to 99% open in the fluid contact scrubbing zone and allows the scrubber to deliver exceptionally high gas throughput capacity - over three times greater than comparable size packed towers or tray scrubbers for higher scrubbing efficiency in a smaller diameter vessel.

Designed to handle gas capacities from 500 thru 25,000 cfm, RotaBed is available in mild steel, 304, 316, and AL6XN Stainless Steels, High Nickel Alloys, Titanium FRP, FRP-Dual Laminate, and Polypropylene. Pressure drop range is 1..75" thru 15" w.c. with particulate removal efficiencies of 3 microns and above from 97 to over 99.9%, and water soluble gases up to 99.99%

How It Works

During operation, gas with contaminants enters the RotaBed gas inlet(1) and flows upward. Scrubbing liquid is introduced through fully open non-clog pipe distributors(2) onto the surface of the patented RotaBed Coriolis induced fluidizing grid(3). Single or multiple grid stages are incorporated depending on the number of transfer units required to meet the needed pollutant removal efficiency. The high velocity gas travels in an angular upward path and fluidizes the liquid on the large open area grid surface. Unlike low efficiency static plug flow fluidized beds, the RotaBed shaped grid design utilizes swirl inducing vanes(4) to dramatically increase mass transfer and particulate collection via creation of a rotating Coriolis motion fluidized bed(5). Scrubbing liquid with captured pollutants then vortex drains(6) into the slump(7). The RotaBed cleaned gas passes through a two stage droplet removal stage(8) and exits through the gas outlet(9).



How RotaBed™ Works

www.bionomicind.com

Handle virtually any bulk solid material

Flexicon stand-alone equipment and automated plant-wide systems convey, discharge, condition, fill, dump and weigh batch bulk materials dust-free

Flexicon engineers and manufactures a broad range of equipment that handles virtually any bulk material, from large pellets to sub-micron powders, including free-flowing and non-free-flowing products that pack, cake, plug, smear, fluidize, or separate.

Individual bulk handling equipment includes: flexible screw conveyors, tubular cable conveyors, pneumatic conveying systems, bulk bag dischargers, bulk bag conditioners, bulk bag fillers, bag dump stations, drum/box/container dumpers, and weigh batching/blending systems. Each of these product groups encompasses a broad range of models that can be custom engineered for specialized applications, and integrated with new or existing upstream and downstream processes and storage vessels.

All equipment is available to food, dairy, pharmaceutical and industrial standards.

For large-scale bulk handling projects, Flexicon's separate Project Engineering Division provides dedicated Project Managers and engineering teams on four continents to handle projects from concept to completion. Working with each customer's preferred engineering firm or directly with their in-house team, Flexicon adheres strictly to the customer's unique standards, documentation requirements and timelines through a single point of contact, eliminating the risk of coordinating multiple suppliers.

Flexicon's worldwide testing facilities simulate full-size customer equipment and systems, verify performance prior to fabrication, demonstrate newly constructed equipment for visiting customers, and study the performance of new designs.

Flexicon offers stand-alone bulk handling equipment as well as plant-wide systems integrated with new or existing processes

In 2015 the company doubled the size of its manufacturing facility and world headquarters in Bethlehem, PA, and also operates manufacturing facilities in Kent, United Kingdom; QLD, Australia; and Port Elizabeth, South Africa.

www.flexicon.com

Get on the right wavelength

Endress+Hauser's level measurement range offers the right answer for each application

A full range of operating frequencies makes it easy to choose the best one for each application

Endress+Hauser has completed its radar level measurement portfolio with the new Micropilot FMR60, FMR62 and FMR67. The Micropilots are the first 80 GHz instruments to follow the safety-by-design concept and to be developed according to IEC 61508. They are also the first level instruments to support Heartbeat Technology, as already used in many of the company's flowmeters.

At the beginning of 2016 Endress+Hauser launched the Micropilot NMR81, the first high-accuracy instrument based on 80 GHz technology for tank gauging in chemical, oil and gas applications. Now the company has introduced the Micropilot FMR6x models, which promote safety and simplicity alongside high accuracy.

For the first time, an 80 GHz process radar is available that follows the safety-by-design philosophy, thus making customers' lives easier in terms of safety. The new products also offer a wide selection of Ex approvals.

Improved focusing of the radar signal as well as dynamic processing algorithms provide reliable, stable measurements with a range of up to 125 m and an increased measuring accuracy of ±1 mm. Measurements are unaffected by baffles or other obstacles on the tank walls. Thanks to the innovative antenna design, the system also ignores product buildup and condensation. Interactive software makes commissioning fast and easy.

Instruments with their own "pulse" – the so-called Heartbeat Technology – have so far appeared mainly in Endress+Hauser's flow measurement range. The addition of Heartbeat to the new radar gauges allows documented verification of every measured value, as well as facilitating trend recognition by collecting data for predictive maintenance. Automatic test protocols and a guided SIL proof test ensure that each instrument meets standards for safety and accuracy at all times.

Endress+Hauser uses the slogan "113 GHz + Your Wavelength" for its radar technology to emphasize how individual customers' needs are best met by a full range of frequencies (see image, above). 1 GHz, for example, is used for guided radar in applications involving foam and liquids of low dielectric constant. 6 GHz is best for turbulent liquids and heavy condensation. 26 GHz provides tight focusing and is suitable for 90% of applications, even those involving turbulence. 80 GHz provides the best focus (a 3-deg. beam angle), a measuring range of up to 125 m, and the highest accuracy.

In the end, radar is not the best solution for every application. Endress+Hauser therefore offers a complete portfolio of level measurement technologies. **www.yourlevelexperts.com/en**

KROHNE Adds Six New Transmitters for OPTIWAVE FMCW Radar Level Transmitters

Devices specially designed for solids, powders or liquid applications

Peabody, MA: **KROHNE, Inc**. announces six new 24 and 80 GHz transmitters for its OPTIWAVE series of frequency-modulated continuous-wave (FMCW) radar level transmitters. The transmitters are designed for solids, powders or liquid applications in a wide range of industries. Each device has a particular application target area, including agitated and corrosive liquids, narrow tanks with internal obstructions, or powders and dusty atmospheres.

All new OPTIWAVE devices feature 2-wire 4...20mA HART 7 communication and come with an extensive choice of process connections, starting from -inch. They feature a large backlit LCD display with 4-button keypad, a quick setup assistant for easy commissioning, and free PACTware™ device type manager (DTM) with full functionality. Hazardous area approvals are available, while others, including safety integrity level (SIL), are in process.

New devices for solids include the OPTIWAVE 6400, a 24 GHz FMCW radar for solids from granulates to rocks in industries such as minerals and mining, chemical, agriculture, or power generation; and OPTIWAVE 6500, a 80 GHz FMCW radar for powders and dusty atmospheres, equipped with special features that meet the challenges linked to fine powders such as dust, low-reflective media, build-up, and uneven surfaces.

The new line of 24 GHz and 80 GHz transmitters complement the two existing 6 and 10 GHz devices used with the OPTIWAVE series.

About KROHNE

KROHNE is a worldwide technological leader in the development, manufacture and distribution of accurate, reliable and cost-effective measuring instruments for the process industries. KROHNE focuses on forming partnerships with its customers to provide them with the most reliable and innovative solutions available in the marketplace. For more information about KROHNE's complete line of measuring instrumentation for the process industries, contact KROHNE at 1-800-FLOWING (978-535-6060 in MA); fax: (978) 535-1720, email: info@KROHNE.com, Twitter, Facebook, or visit **www.us.krohne.com.**

Ultra-high speed powder dispersion made simple

Ross SLIM Technology employs high shear for rapid and complete mixing of powders into liquids, avoiding agglomerates and dust formation

The **Ross** Solids/Liquid Injection Manifold (SLIM) is a technology for dispersing challenging powders like fumed silica, gums, thickeners and pigments using a specially modified high shear rotor/stator generator.

In both batch and inline designs, the SLIM is easy to retrofit into almost any process. In an inline set-up, the SLIM mixer pumps liquid from the recirculation tank while simultaneously drawing powders from a hopper. As the liquid stream enters the rotor/stator assembly, it immediately encounters the powder injection at the high shear zone. The mixture is then expelled through the stator at high velocity and recirculated back into the tank. In just a few short turnovers, solids are completely dissolved or reduced to the desired particle size.

This method for high-speed powder injection is ideal for dispersing small concentrations of hard-to-wet solids like CMC or xanthan gum (>5%). It is equally effective for solid loadings as high as 70%, as in the case of titanium dioxide or magnesium hydroxide slurries. By introducing solids sub-surface where they are instantly subjected to vigorous agitation, issues like floating powders, excessive dusting and formation of stubborn agglomerates ("fish eyes") are eliminated. Because the SLIM generates its own vacuum for powder induction and does not rely on external eductors or pumps, it is free of clogging and simple to operate.

Several models are available including automated skid packages where the SLIM mixer is piped to a jacketed tank and supplied with flowmeters, load cells, solenoid valves, level sensors and thermocouples all integrated into a PLC Recipe Control Panel. Each ingredient addition and process step can be pre-programmed so that mixer speed, mixing time, temperature, composition and batch weight are accurately replicated in every run.

Ross Inline SLIM powder induction mixer with built-in control panel mounted on a portable cart with work bench

Established in 1842, Ross is one of the world's oldest and largest manufacturers of process equipment, specializing in mixing, blending, drying and dispersion. **www.highshearmixers.com**

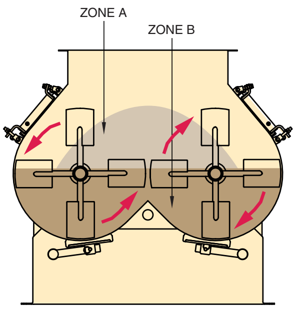
Fast, homogenous mixing

The Bella XN fluidized zone mixer from Dynamic Air is a twin-shaft design that uses a "weightless" central fluidized area to provide thorough yet gentle mixing of dry products

The twin-shaft Bella mixer

The Bella fluidized-zone twin-shaft paddle mixer by **Dynamic Air** achieves fast, high-capacity, low-shear, precision mixing of either dry bulk solids or liquids with solids. Regardless of particle size, shape or density, materials are mixed with a fast, efficient, and gentle action, with typical mixing times of 15–30 s. A weightless zone created by low-speed counter-rotating paddles generates low friction without shear. This makes it ideal for abrasive products and fragile products that cannot tolerate rough handling. Even flakes or spray-dried bodies remain intact.

The Bella mixer consists of twin drums which have two counter-rotating agitators with specifically angled paddles. The paddles sweep the entire bottom of both mixer drums and yet allow the mixer to be started under full load (Figure 1). The material in the mixer moves in a horizontal counter-clockwise direction at the perimeter while simultaneously moving both left and right in the center (Figure 2). The material in Zone B (Figure 1) is in its normal gravimetric state as it is being moved and dispersed. In Zone A, a weightless zone is created which effectively lifts the ingredients to an almost weightless state, allowing them to move freely and randomly, regardless of particle size and density. Thus the two zones' interaction becomes highly efficient as every particle moves rapidly to create a highly homogeneous mix, the key to the Bella mixer mixing technology for fast, precise mixing.



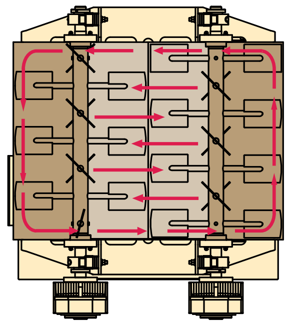


Figure 1 (right, top): In Zone A, fluidization promotes thorough mixing. Figure 2 (right): Material interchange between the two drums

The Bella mixer is available in stainless steel and mild steel construction.

www.dynamicair.com/products/mixers.html

A wide range of custom material handling equipment

Material Transfer is a premier manufacturer of custom material handling equipment, with products including bag conditioners, dischargers, and filling systems

Material Transfer's Bulk Bag Conditioners ensure that products are free-flowing

Material Transfer is an industry leader in the custom design and manufacture of material handling equipment and systems for dry powders and bulk solids. A unique combination of application-focused engineering, award-winning designs and exclusive features results in equipment that offers class-leading quality, value, durability, ease of use, and performance.

Equipment is fully assembled, inspected, and factory tested prior to shipment to ensure reliable performance and customer satisfaction, the company says.

Material Transfer's application experience includes pharmaceuticals, food, chemicals, electronics, aggregate, agriculture, foundry, manufacturing, mining, packaging, pet food, petroleum, plastics, plating, stamping, governmental, explosives and automotive. Experience in dust-tight handling of hazardous materials in hazardous environments, with explosion-proof or intrinsically safe equipment, has placed Material Transfer in the forefront of designing and building custom material handling equipment for these applications.

Over 95% of the equipment Material Transfer manufactures is custom-designed for a customer's particular application requirements. Material Transfer has a team of talented engineers with the latest 3-D software for equipment design, professional metal fabricators and machinists with the latest fabrication and CNC machining technologies, and an experienced team of machine assemblers to build its products.

Material Transfer's product line includes:

- Material Master Bulk Bag Conditioners to quickly and safely return hardened materials to a free-flowing state (photo).
- Material Master Bulk Bag Dischargers with patented technology to provide clean, dust-tight discharge.
- Material Master Bulk Bag Fillers – from economical 4-post units to fully automated, high-output PowerFill filling systems.
- Container and drum dischargers to empty containers of any size at heights to 40 ft., with dust-tight Lift & Seal system or open discharge, and patented system that allows 180° rotation.
- Integrated systems to meet customers' requirements.

www.materialtransfer.com

Don't "just toss it": GEA puts safety first with explosion- and corrosion-safe decanters.

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Explosion-proof decanters and separators are therefore equipped with certified electronics and a safety lock to protect against intense oscillation. They can be used in Zone 1 environments (areas where an explosive mixture of air and flammable gas, vapor or mist may form under normal operating conditions) and in Zone 2 (areas where an explosive mixture of air and flammable gas, vapor or mist is unlikely to occur under normal operating conditions, or if so, only briefly).

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Explosion-proof decanters and separators are used in a variety of specialized chemical and pharmaceutical applications Examples include, the production of oil additives, the pharmaceutical extraction of pectin, xanthan, rubber, special chemical substances and peroxides, in the recovery of catalysts, as well as in agrochemicals and in polymer production. They are gastight, and flushed with inert gas. Flammable mixtures cannot arise as there is no way for oxygen to come into contact with the material separated in the centrifuge.

The use of standard components also ensures that no unnecessary delays are incurred when maintenance is required.

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GEA decanter ecoforce

GEA separator TTI

A Recipe For Success

PSL and C.O.P.E. have come together with a unique offering, leading you through the process.

Powder Systems Limited (PSL) have expanded their expertise in process development with the innovative development facility, C.O.P.E. (Center of Process Excellence).

Visitors to Interphex New York in April, will be able to see how both services can provide solutions to your process requirements from laboratory and R&D, up to production.

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PSL will demonstrate how laboratory filtration and drying studies are made easy with the next generation GFD automated bench top Lab Filter Dryer. Also available to see will be PSL's unique MSR

MicroSphere Refiner for microsphere formulation. Decades of experience in sterile production has led PSL to develop this ground breaking product, providing a solution to overcoming the typical manufacturing challenges associated with microsphere production which is experiencing growing demand due to its revolutionary applications.

Leading you through the process, with two exceptional services being offered at Interphex this year.

Join us in New York on Booth 2232.

www.powdersystems.com

Experience PSL's unique MicroSphere Refiner

Integrated Process Containment Solutions

Micronizing isolator integrating new 4th generation MC DecJet spiral jet mill for particle size reduction below 1 micron.

This half suit isolator has been designed to guarantee high operator protection during the micronizing process for particle size reduction below 1 micron.

The micronizing takes place as a linear process with an area being provided in the work surface of the chamber. HPAPI's are automatically fed into the feeder hopper by a Powder Transfer System (PTS) drawn from the previous process station. This operation is connected to the PLC which controls the level inside the feeder by use of level sensors. From there the product is conveyed into the venturi of the micronizing jet mill and further into the grinding chamber. Grind gas is fed into the outer chamber of the jet mill from where it is forced through the jet nozzles spaced around the periphery of the chamber. Micronized product is conveyed to an integrated cyclone filter allowing contained access to the cyclone filter sleeves.

Product from the cyclone is discharged into a buffer vessel from where it is further conveyed via PTS Powder Transfer System to a contained pack off station.

The micronizing isolator has been designed fully CIP using a series of spray nozzles and spray guns strategically positioned throughout the system.

www.dec-group.net

Containment Solutions Prevent Contamination

Safe protection for humans, products and the environment from Müller Systems & Handling

The **Müller** Containment Valve (MCV) is an application solution for the handling and the containment of goods that are used for the manufacturing of highly-effective pharmaceutical powders or tablets. MCV is a robust and solid split butterfly valve system, OEL < 1 µg / m³ (OEB-Level 5, SMEPAC). The modular designed MCV can be perfectly adapted to pharma containers, tablet presses, blenders, grinders, sieves and all containers used in closed manufacturing systems. It protects chemicals, humans and the working environments from contamination, as required by REACH.

"More systems and handling solutions for the chemical and pharma industries will be at display at ACHEMA 2018 show in Frankfurt/Main at Hall 3.1, Stand A75", promises Christian Lamp, who has joined Müller Systems & Handling as product manager in October 2017 to deal with all topics regarding application solutions for the handling and the containment of goods that are used for the manufacturing of highly-effective pharmaceutical powders or tablets.

www.muellersyshand.com

IPCO*

Efficient micro-pastillation for high solubility chemicals

The solidification of chemical products into a solid pastille form allows easy storage, handling, dosing and reprocessing, and for some, the smaller the pastille, the more efficient the process.

The key advantage of pastilles as small as 1-2 mm diameter – known as micro-pastilles – is that they are easier to dissolve, remelt or mix, resulting in a product of high homogeneity. In some cases, this efficiency can enable lower dosing for material savings.

Chemical applications

The **IPCO*** Rotoform system is widely used across the chemical industries for products such as fatty alcohol blends, waxes, resins, hot melts and plastic additives like UV stabilizers.

Rotoform pastillation process

With around 2,000 installations around the world, this is the most successful chemical granulation system of its kind.

The Rotoform itself consists of a heated cylindrical stator, which is supplied with liquid product, and a perforated rotating shell that turns concentrically around the stator.

Micro-droplets of the product are deposited across the width of a continuously running stainless steel belt. Heat released during solidification is transferred via the steel belt to cooling water sprayed underneath, and the solidified pastilles are cleanly discharged at the end of the system.

Rotoform features

Every aspect of the system is designed to ensure premium quality pastilles, low operating costs and maximum availability (approximately 8,500 hours per year). It is an environmentally-friendly process with low sound and low dust emissions, and a closed cooling water system means no possibility of cross contamination between water and end product.

Technical challenges

- Production of the outer shell is very difficult with up to 50 000 holes in the rotary shell.
- High precise gap adjustment between rotary shell and steel belt. The distance between belt and Rotoform is so small that the product, when it protrudes from the bores, is dragged along by the belt.
- Sophisticated belt tracking system required, otherwise micro-droplets will be linked to each other.

* IPCO, former Sandvik Process Systems, is now operating as an independent business within FAM AB, part of the Wallenberg Group.

www.ipco.com

Flare Selection for the CPI

There are many factors to consider when selecting a flare system for CPI sites that can impact safety, operating costs and environmental performance

Anu D. Vij
Ship & Shore Environmental

Flaring has long proven to be an effective technology for disposing of gases that cannot be used otherwise. Different flaring techniques are utilized in the chemical process industries (CPI), depending on environmental regulations, site requirements and process needs. Different flare technologies offer tradeoffs among equipment cost, operating expense, design complexity and process requirements. Selecting the proper flare equipment can result in optimized capital and operational costs while maintaining compliance with environmental requirements. Before a flare type is selected, it is important to understand the environmental impacts, process requirements and economic considerations of a particular operation or project. Improper application of a flare technology can lead to not only poor performance, but also negative environmental impacts, which can later result in significant costs and legal implications. This article provides details of the different types of flares used at CPI sites and their selection criteria.

Flare design

A flare is a device used to safely dispose of unwanted or excess gases and liquids from normal, unplanned or upset conditions during process operations in CPI sites. Flaring is done by burning off the gas or liquid into the atmosphere. The gases or liquids to be combusted are usually rich in heat content, enabling them to self-sustain the combustion without the need for additional external combustion gas.

A typical flare consists of a gas inlet connected to a flare header. Combustion is achieved through an ignition device located at the ground level and a pilot burner tip located at the top of the flare header. The gas to the pilot is usually provided from a utility source. A water seal or purge-gas arrangement is used to prevent any flashback into the process stream. A flare usually generates water vapor and CO_2, which are discharged into the atmosphere.

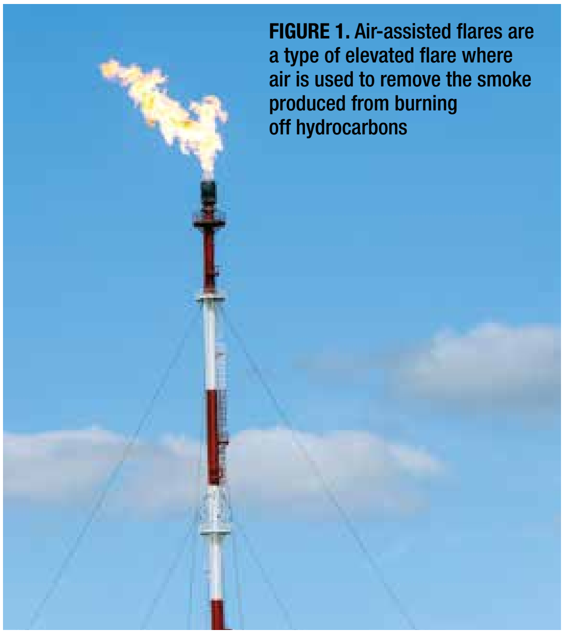

FIGURE 1. Air-assisted flares are a type of elevated flare where air is used to remove the smoke produced from burning off hydrocarbons

Flare types

Flares are classified into two common types: elevated and ground flares. Elevated flares are the most widely used flare type in CPI sites. In elevated flares, the gases are combusted using flare headers that are located at a considerable height above the ground. Elevated flares are again classified into several types, depending on the type of gas, the incoming gas pressures, smoking or non-smoking requirements, heat radiation levels and location. Elevated flares have an open flare associated with them. An open flare consists of a visible flame that generates heat and some noise.

Ground flares are systems where the combustion of the gases takes place at the ground level. Since these flames are close to the ground, they have to be enclosed in a refractory-lined chamber or enclosure. As combustion takes place at the ground level, gases are released close to the ground, resulting in poor gas dispersion. Due to these limitations, enclosed ground flares are commonly used in situations where the gases to be burned are relatively clean and when reducing noise pollution is critical.

Elevated and ground flares used at CPI sites can be further classified into two types: single-point and multi-point flares. Single-point flares are typically oriented to fire upwards. Single-point flares can be smokeless or non-smokeless using air-assisted or steam-assisted designs, and are suitable for low-pressure applications. Multi-point flares are designed for higher-pressure applications and where smokeless burning is required. Multi-point flares are used to improve the burning by applying multiple burning points. These can be located on the ground level or at an altitude using boom supports.

Single-point elevated flares

Utility flares. These are elevated flares that are commonly used for low-pressure natural-gas flaring. They are used for non-smokeless flaring of heavy hydrocarbons present in gas streams. They are mostly emergency-only flare systems. Their key design features a double-thick flame-retention ring and they work with all types of ignition systems.

Air-assisted flares. These flares are also elevated flares used for smokeless flaring of heavy hydrocarbons. They are commonly used where low-pressure waste gas is present. Air-assisted flares (Figure 1) use air to surround the gas during the combustion. The air removes the

smoke that is present when burning off heavy hydrocarbons. The flares' design features multiple flare-tip devices with a large air-fuel boundary in the enclosure.

Steam-assisted flares. This type of elevated-flare system utilizes steam to remove the smoke generated upon combustion of heavy hydrocarbons. They are very similar to air-assisted systems, except steam is used instead of air.

Sonic flares. Sonic flares are typically used when the gas to be flared is under high pressure. Smokeless flaring of heavy hydrocarbons at high pressures is done using these types of flares. Sonic flares usually operate at Mach 1 speeds. They are associated with lower stack heights due to the high velocity requirement. Low radiation is required for such applications.

Portable flares. Portable flares are used in situations where a vessel or a tank needs to be evacuated for maintenance purposes. They are also used as temporary flares during a facility shutdown or when bypassing of the main flare is required.

FIGURE 2. Multi-point flares divide the gas stream into multiple streams and burning points

All types of flares require some sort of structural support, due to the height requirements. The commonly used flare supports for onshore applications are guyed wires, freestanding and derrick support types. Some of the derrick support types are demountable for maintenance purposes. Permanent boom structures used in production flares are arranged at a 15–45 deg angle from horizontal.

Multi-point flares

Multi-point flares (Figure 2) are used when improved burning performance is required. Here, the gas stream is divided into multiple streams and into multiple burning points. They can be arranged near grade or in elevated booms. For CPI sites, multi-point flares are designed to achieve smokeless burning.

Enclosed ground-flare systems

Enclosed flares (Figure 3) are installed in situations where flame visibility is unacceptable. They feature flares at the ground level and come into play when measuring flare emissions is required. The gases treated are typically low-flow and low-pressure exothermic waste streams. These flares are required in areas where heat radiation must be kept to a minimum. Enclosed flare systems come in both natural and forced-draft types. Usually, the combustion chamber is a steel structure lined with refractory material. Most of the units are temperature-controlled with sample ports available for measurements.

Safety considerations

The primary safety concern for flares is thermal radiation. Special consideration must be given to thermal radiation for flares that are located close to the boundaries of CPI sites. Safety regulations must be followed by plant operators to ensure that flares are operated in safe zones in a responsible manner. Often, the safest operations can be accomplished by increasing the flare height or putting up restrictions (such as signs or barriers) denoting the area as a low-access area. Enclosing the flares is another way of limiting radiation in plants that have limited area for use.

Smokeless flares are sometimes desired in areas that are environmentally sensitive. Air-assisted or steam-assisted flaring is utilized in such instances to convert the flares to smokeless flares. Combustion gases from flares that mix with indoor air can cause serious problems when inhaled. Therefore, adequate ventilation is required in facilities that are located close to flares. Companies must assess the toxicity of the gases that are being emitted and implement appropriate measures if

there is a health risk if these gases are inhaled.

Noise pollution is another safety concern when flaring of gases occurs. Workers or personnel exposed to the noise over a continued period of time have experienced hearing loss or other auditory problems. Companies must provide personal protective equipment, such as ear plugs or other protection, for prolonged exposure to the noise generated by flares.

Finally, it is imperative for companies to engage in emergency planning and prevention measures in case of any flare malfunction. The potential risk to workers in the event that a flare does not function properly is a serious safety concern. Regular maintenance is required to ensure that the flares are functioning properly, and that there is always a backup plan in case of such emergencies.

Design plays an important role in the safety of flares. Some of the key parameters that need to be considered while designing a flare include spacing, location, height, capacity and flashback.

Radiant heat can be minimized if the flare is located at a safe distance from buildings and office spaces. Therefore, it is important to have enough space available in case of any mishaps. Flare height is also an important safety design consideration. The height of the flares must be such that it prevents any burnt material from falling down onto the ground. Also, height is taken into consideration during air-dispersion modeling studies to prevent hazardous materials from entering breathing air.

Flare capacity must be sized so that it is large enough to handle gas releases from relief valves, emergency systems and blowdowns from different processes. Improperly sized flares can lead to flare damage and can also cause explosions. Finally, flashback is a situation where flames can travel back into the process piping. To prevent flashback, flares are designed with water seals or purge-gas systems.

Flare performance

Flares usually operate at a combustion efficiency of 98% for converting organic compounds to CO_2 and water vapor. Greater than 98% efficiency is achievable if the flares are properly designed. The key parameters to measure the performance of flares are the following:

1. Thermal radiation
2. Smokiness using the Ringelmann smoke chart (Figure 4)
3. Flame intensity
4. Combustion efficiency
5. Emission levels
6. Noise levels
7. Pilot flame stability

The following paragraphs provide details on testing methods used to measure flare performance.

Ringelmann chart. A Ringelmann chart is commonly used to measure the smokiness of a flame. The Ringelmann scale, as shown in Figure 4, ranges from 0 to 5, based on the level of visibility. Flares that have a good performance usually range in the lower scale values. A black

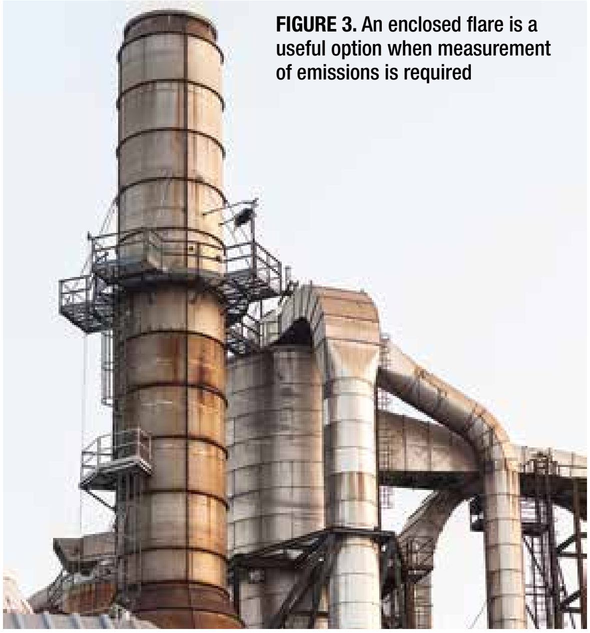

FIGURE 3. An enclosed flare is a useful option when measurement of emissions is required

Ringelmann 0	0% opacity — clear	
Ringelmann 1	20% opacity — barely visible	
Ringelmann 2	40% opacity — clearly visible	
Ringelmann 3	60% opacity — somewhat transparent	
Ringelmann 4	80% opacity — barely transparent	
Ringelmann 5	100% opacity — black	

FIGURE 4. The Ringelmann Smoke Chart measures the smokiness of a flame, which helps to quantify flare performance

flame with a scale of 5 indicates a very smoky flame. A clear flame with a scale of 0 indicates a fully smokeless flame.

Thermal radiation. Thermal radiation is measured using sensors and radiant heat-flux monitors. These usually give a measure of either the solar and flare radiation combined or just the flare radiation levels alone.

Flame intensity. Flame intensity and lengths are measured using flame intensity monitors. These devices use single-wavelength sensors to detect flame intensity and also have capabilities to measure flame lengths.

Combustion efficiency. With recent technological advancements, combustion efficiency is now measured using Fourier transform infrared (FTIR) methods. FTIR uses remote-sensing technology to detect combustible products, such as carbon dioxide, carbon monoxide and select hydrocarbons. Conventional, non-FTIR measurement techniques rely on calculations using derived carbon-balance and tracer-injection methods.

Emissions levels. Emissions levels from flares are difficult to determine. This is because flares do not contain emissions after combustion has taken place. Typical methods to evaluate emissions are inferred measurements, which take into account the amount of gas flared, along with emission and oxidation factors.

Noise levels. Noise levels are measured using noise meters at different points in the flare. Noise levels are classified as sound pressure levels or sound power levels as functions of either pressures or flowrates.

Pilot flame stability. Pilot flame stability is usually tested using scanning devices, such as ultraviolet (UV) scanners. The stability of pilot flames is important to monitor because it keeps the flare burning and indicates reliable operations.

Performance expectations

Table 1 shows what performance levels are to be expected for different types of flares.

With all the different performance factors that can influence the selection of a flare system, it can be difficult to determine where to start the process of designing and selecting a flare technology. By evaluating the design considerations discussed in this article, engineers can assess the available technologies and the performance expectations of each flare before beginning the flare selection process. Selecting the right flare is critical for the overall design of a process from the safety, environmental, economic and social impact point of view. The correct flare choice will ensure that the flare can meet its objective, which is safely disposing of waste gases and liquids into the atmosphere. ■

Edited by Mary Page Bailey

TABLE 1. FLARE PERFORMANCE LEVELS

Flare Type	Performance factor	Performance levels
High-pressure flares	Radiation	Low
	Flame shape	Stable
	Flame tip	Long tip life
Utility flares	Smokiness	Low
	Combustion efficiency	High
	Pilot flame stability	Good
Air-assisted flares	Smokiness	Zero
	Radiation	Low
	Flame tip	Long tip life
	Emissions (NO_x, CO)	Low
Multi-point flares	Smokiness	Zero
	Flare life	long
Steam-assisted flares	Smokiness	Zero
	Radiation	Low
	Flame tip	Long tip life
	Emissions (NO_x, CO)	Low
Enclosed combustion flares	Smokiness	Zero
	Flame length	Short
	Combustion efficiency	High

Author

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The *CE* Plant Cost Index: An Update

Changes in the availability of source data for the *CE* Plant Cost Index periodically necessitate updates to how the index is calculated

Scott Jenkins
Chemical Engineering magazine

FIGURE 1. The AOIM data series (orange) has more closely tracked the now-discontinued CMMEP series (yellow) over the period from 2007 until 2015, than has the broader MSIM data series (shown in green)

The *Chemical Engineering* Plant Cost Index (CEPCI) is a widely used tool for comparing plant construction costs in the chemical process industries (CPI) between different time periods since 1963. Over its history, the underlying details of the index have been revised and adjusted several times. For a discussion of these changes, readers are directed to *Chem. Eng.*, January 2002, pp. 62–69. This article aims to explain the most recent change that has been made to the CEPCI.

The CEPCI

The *CE* Plant Cost Index is actually a composite that consists of four sub-indices: Equipment; Construction Labor; Buildings; and Engineering and Supervision (see Table 1). The Equipment subindex is itself a composite of seven other indices, each focusing on a particular category of process equipment. The component indexes are compiled, and weighting factors are applied to make up the Equipment subindex. The three other subindexes are compiled independently from appropriate inputs. Information on these four indexes has been reported running back to 1947.

After weighting and normalizing the values, the four sub-indexes are combined to constitute the CEPCI. For each year in the past, an annual value for the CEPCI is calculated based on the arithmetic mean of 12 monthly values for a given year. CEPCI data from previous years can be found and downloaded at www.chemengonline.com/pci.

BLS data

As many users of the index know, the CEPCI uses specifically selected producer price index (PPI) data and other data from the U.S. Bureau of Labor Statistics (BLS; Washington, D.C.; www.bls.gov), which is a part of the U.S. Department of Labor. Relevant PPI information reported by the BLS is collected by *Chemical Engineering* editors and used to calculate the monthly changes to the CEPCI. BLS says it is the "principal Federal agency responsible for measuring labor market activity, working conditions, and price changes in the economy." It collects and analyzes many types of economic information to assist decision-making in the public and private sectors.

TABLE 1. CE PLANT COST INDEX COMPONENTS

Equipment
- Heat exchangers & tanks
- Process machinery
- Pipe, valves & fittings
- Process instruments
- Pumps & compressors
- Electrical equipment
- Structural supports & misc.

Construction labor
Buildings
Engineering & supervision

A portion of the input data for the CEPCI is derived from the BLS's PPI data. As the BLS defines them, producer price indexes "track the average change in net transaction prices that domestic producers in the mining, manufacturing, agriculture and forestry sectors, as well as certain service industries, receive for the products they make and sell." BLS economists and analysts review a statistically chosen representative sample of price quotations in business transactions to build its set of PPIs. Overall, There are around 13,000 PPIs covering more than 600 industries.

A carefully selected group of 41 PPIs is used as raw input to the CEPCI. The set represents a diverse set of materials and components that go into the construction of a CPI facility, including steel plates, concrete pipe, tanks, fans, piping and many others. In addition, the CEPCI uses 12 labor-cost indexes, which are also compiled by BLS.

Making a change

Periodically, the BLS makes changes to the data that they collect and report, some of which necessitate changes in how the CEPCI is calculated. The *Chemical Engineering* editorial team wanted to make *CE* readers aware of one such change that is reflected in this month's CEPCI on p. 88.

Since the advent of the CEPCI in 1963, one of the inputs has been a PPI data series entitled "Chemical Manufacturing Machinery, Equipment and Parts." For the purpose of brevity in this article, we will call this data series "CMMEP."

In autumn of 2015, BLS ceased reporting data for that series, because the information that could be collected did not meet the requirements BLS has established for reporting a data series, including the requirement for a minimum number of reporting units. In some cases, a given PPI may not be reported for several months because the information available does not meet BLS guidelines for reporting, only to return later once available information again meets the reporting criteria. So the absence of data for a particular PPI in a given month is not necessarily a reason to change anything in how the CEPCI is calculated.

However, in the case being discussed in this article, it became clear over the next several months that the CMMEP series would be discontinued permanently, and the series would be subsumed by a broader PPI data series known as "Miscellaneous Special Industry Machinery" (MSIM).

Once the CMMEP was discontinued permanently, the *CE* editorial team began conversations with BLS economists to inform the magazine's efforts to determine whether or not the MSIM should be included in the CEPCI as a substitute for the now-discontinued CMMEP. During this time of evaluation, we continued to use the last available data for the now discontinued series to continue to calculate the CEPCI.

CE editorial staff observed the trends in the broader MSIM data series over the past 10 years and compared it to that of the discontinued CMMEP series over the same time period. Unfortunately, the MSIM series did not closely follow the same trends observed in the narrower CMMEP series over the period between 2005 and 2015, indicating that the MSIM would not necessarily be a suitable direct replacement as an input to the CEPCI.

After further consultation* with BLS staff economists and examination of the scope of the MSIM, it was noted that part of the reason for the lack of similarity between the two data series seemed to be that the MSIM included equipment and processes for the semiconductor manufacturing industry. The ways in which specialized equipment has changed for the semiconductor industry sector have been different from how specialized equipment has changed in the CPI over the past 20 years, leading to situation where the data from two series have decoupled and diverged.

The *CE* editorial team then worked with BLS economists to identify an alternate data series that more closely tracked the data from the discontinued CMMEP series. One series that emerged as a possibly good candidate for replacing the discontinued data series is a PPI Industry series known as "All Other Industrial Machinery" (AOIM).

Replacement series

The AOIM data series differs slightly from the other inputs to the CEPCI, in that it is an industry-based PPI, rather than a commodity-based PPI, as the other CEPCI inputs are. However, economists generally agree that it is possible for the two types of data series to be used together in an aggregate index, such as the CEPCI.

Over the past 12 years, the AOIM data series has tracked much more closely to the discontinued CMMEP series. The similarities can be observed by plotting the values of two data series over time (see Figure 1).

Starting with the March 2018 edition of CEPCI, we began using the monthly changes observed in the AOIM PPI index to adjust the historical data from the discontinued PPI data series. This entails tracking the AOIM and observing the month-to-month changes in that index. These changes, expressed as a percentage, will be applied to the last available value from the discontinued series to derive a new value to input to the CEPCI. This new value will be used to calculate the monthly CEPCI.

In this way, the continuity of the CEPCI can be preserved, while taking into account changes to relevant special industry equipment that are being observed in the PPIs.

Over time, this process will improve the accuracy and timeliness of the CEPCI's Equipment subindex as well as the overall CEPCI. We will continue to monitor the input data from the BLS in case further changes are necessary.

The *CE* editors thank the users of the CEPCI for their continued support and attention.

Acknowledgements

The author would like to thank two individuals who provided their time and expertise in support of this article. Jayson Pollack is a supervisory economist at BLS who graciously spent time on several phone calls to explain how BLS produces the PPI and to identify information that could be used for the CEPCI. John Hollmann is a cost engineering consultant and member of *Chemical Engineering*'s advisory board who assisted in outlining a strategy to address the discontinued data series. Thank you both very much for your help. ■

***Editor's note**: Conversations between *CE* staff and BLS economists explored background information on the PPI data series. BLS did not act in an advisory capacity.

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Show Preview

INTERPHEX

Quattroflow

Coperion K-Tron

Marchesini Group

Frewitt USA

Interphex, the annual event focused on pharmaceutical and biotechnology manufacturing, takes place April 17–19 at the Jacobs Javits Center in New York City. This year's event will bring together 11,000 attendees for a technical conference, networking events, technology demonstrations and a large exhibit hall. The technical conference will feature several session tracks, targeting such topics as continuous manufacturing, quality metrics, risk management, formulation and more. The event will also feature roundtable discussions focused on predictive process control, integrity testing and more. This show preview describes a selection of this year's Interphex exhibitors.

New diaphragm pumps with optimal draining capacity

The new QF10k quaternary (four-piston) diaphragm pump (photo) provides a maximum flowrate of 10,000 L/h (44 gal/min). The pump is equipped with an improved, patent-pending stainless-steel pump chamber that provides optimal drainability to maximize product recovery. QF10k pumps also feature a maximum pressure of 6 bars, a 20:1 turndown ratio, linear flow performance and high flow stability, even at low flowrates. Clean-in-place (CIP), steam-in-place (SIP) and autoclave capabilities are also offered. Available accessories include a control box, a power box, a diaphragm sensor and a PID pressure controller. Typical applications for these pumps include chromatography and cross-flow filtration systems. Booth 2253 — *Quattroflow, part of PSG, a Dover company, Kamp-Lintfort, Germany*
www.quattroflow.com

Modularized feeder systems enable easy cleaning

The K3-PH line of pharmaceutical loss-in-weight feeders (photo) features a modular concept and a reduced equipment footprint. The integrated D4 platform scale incorporates the patented Smart Force Transducer (SFT) weighing technology, which quickly provides an accurate weight signal. Smooth, crevice-free surfaces prevent the deposit of dust and product residue and enable easy cleaning, says the manufacturer. The feeder system includes technologies for linearization, temperature compensation and a digital low-pass filter to reduce the effects of vibrations. The feeder's modular quick-change design allows for the exchange of feeder types and sizes, as well as hoppers or agitators, using the same scale and drive for fast adaptation to new processes and formulations, while also streamlining cleaning and maintenance. The system is suitable for multi-feeder clustering in a variety of continuous processes, including direct compression, continuous extrusion, wet and dry granulation and continuous coating, as well as traditional batch processing. The redesigned scale features a trapezoidal arrangement, facilitating a more optimized multi-feeder arrangement in a smaller footprint. In addition, the feeder bowls and hoppers feature a new seal design for enhanced product containment. The modular concept also features a newly developed drive using a servo motor, which offers a much larger turndown range, including lower feedrates. Booth 2261 — *Coperion K-Tron GmbH, Stuttgart, Germany*
www.coperion.com

These emulsifier machines have many configuration options

Turbo-Mek 150 vacuum turbo-emulsifiers (photo) are designed to process liquids and creamy products, including emulsions, serums, oils, gels and lotions. The machine features temperature and vacuum control and a slow mixing action. The homogenizing action is achieved via a turbine placed on the bottom of the vessel. The machine's compact footprint includes stainless-steel feet that serve to level the machine and absorb vibrations. Available options include the following: an additional valve placed on the vessel's front to enable powder loading through the optional specialized hopper; a membrane filter on the vacuum breaker or on the air-pressure entry valve; and a vessel-washing system consisting of water spray balls, water entry valves and a recirculation pump. Booth 3125 — *Marchesini Group, Pianoro, Italy*
www.marchesini.com

A pin mill designed for lab- and pilot-scale operations

The PinMill-Lab (photo, p. 78) is a high-performance pin mill designed for reducing hard or crystalline products down to a particle size having a D90 particle-size distribution of 10 µm. Suitable for processing small-scale laboratory batches of 50 g to 2 kg, the PinMill-Lab also lends itself to be used for pilot-scale production. The device's compact design facilitates simple integration and a quick setup in laboratories, as well as integration into a glove-box. The PinMill-Lab can handle materials with density up to 2 mg/dm^3 and temperatures ranging from –20 to 60°C. The milling head can optionally be integrated into a rigid or flexible isolator. Cryogenic milling options are also available. According to the company, the geometry of the milling housing enables product recovery of up to 99%. Booth 2964 — — *Frewitt S.A., Granges-Paccot, Switzerland*

www.frewitt.com

This isolator system integrates compounding and dispensing

This company's compounding and dispensing isolator system (photo) includes an isolator, vessels, clean-in-place (CIP) skid (with rotating spray balls and wash gun) and valves, all constructed from stainless steel. The negative-pressure isolator runs at –100 Pa differential pressure, relative to room conditions. The isolator ventilation system includes a nitrogen purge function for controlling relative humidity to less than 30%. A fully integrated steam-in-place (SIP) system is available for vessel sterilization. The charging and discharging of the compounding and filtration vessels are controlled via floor scales. The compounding vessel is equipped with a pH probe and meter linked to the SCADA system. Booth 2441 — *Howorth Air Technology Inc., Bayville, N.J.*

www.howorthgroup.com

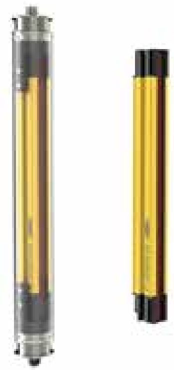
Safety light curtains in hygienic enclosures

EZ-Screen LS safety light curtains (photo) resist high-pressure, high-temperature washdown and aggressive chemical cleaning, and are protected by hygienic tubular enclosures, making them suitable for use in food, beverage and pharmaceutical applications. Made of FDA-grade polycarbonate tubes and 316L stainless-steel endcaps and mountain brackets, each enclosure has a smooth, hygienic design that minimizes the opportunity for debris to accumulate. The enclosures will withstand exposure to chemical cleaning agents and will not become cloudy or discolored over time, ensuring reliable light-curtain performance. A hydrophobic vent allows condensation to escape the enclosure and prevents water and chemicals from entering, eliminating the need for an integral heater element. EZ-Screen LS systems include highly visible alignment indicators and intuitive diagnostics to simplify setup and facilitate troubleshooting. Dual-scan technology makes the sensor immune to ambient light. The sensing range for these devices is up to 8.4 m (27.6 ft). Booth 2153 — *Banner Engineering, Minneapolis, Minn.*

www.bannerengineering.com ■

Mary Page Bailey

Howorth Air Technology

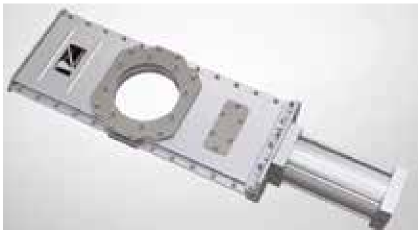


Banner Engineering

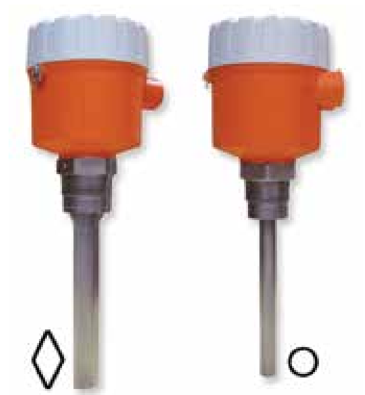
Show Preview

INTERNATIONAL POWDER & BULK SOLIDS CONFERENCE & EXHIBITION

B&P Littleford



Vortex Global



Monitor Technologies

Schenck Process

The International Powder & Bulk Solids Conference & Exhibition (iPBS) is taking place April 24–26 at the Donald E. Stephens Convention Center in Rosemont, Ill. This event will draw over 3,500 professionals from around the globe who specialize in powder and bulk solids technologies. The event features a technical conference that will include panel discussions with industry experts covering dust explosions, pneumatic conveying and mixing, sampling and segregation. The event's exhibit hall will showcase 350 exhibiting vendors who will display their products and services. This year, the exhibit hall will offer guided tours targeted to several critical topics, including bulk storage, pneumatic conveying and dust control. The following is a small selection of the products and services that will be highlighted at this year's iPBS exhibit hall.

These plow mixers are well suited for pressurized reactions

This company's plow mixers (photo) provide medium- or high-intensity mixing action, excellent heat transfer for drying, and the mixers' cylindrical body lends itself to pressurized reactions and serializing applications. Units can be tailored to each application and manufactured to comply with industrial and sanitary standards. The mixers' design allows for multiple processes to occur in a single vessel. Available mixer capacities range from 5 to 30,000 L. Rental equipment for in-house process development is also available, along with testing services. Booth 2429 — *B&P Littleford, Saginaw, Mich.*
www.bplittleford.com

Orifice gates to handle powders, pellets or granules

This company's Quantum orifice gates (photo) are specifically engineered for handling dry bulk powders, pellets and granules in gravity flow, pneumatic (dense and dilute phase) or vacuum conveying systems with pressures up to 15 psig, depending on size. The orifice gates feature wear-compensating hard polymer seals that are protected from the material flow stream. Standard sizes available range from 1 to 16 in. (50 to 400 mm), with various options for materials of construction. Operations are safer due to the elimination of pinch points and exposed moving parts, says the company. Booth 2135 — *Vortex Global, Salina, Kan.*
www.vortexglobal.com

Durable and versatile vibratory level sensors

The DuraVibe Series of vibratory-style level sensors (photo) for powders and bulk solids consists of the Model PZP and Model VibraRod sensors. Both models have been designed to offer hazardous-location protection with intrinsically safe probes. DuraVibe sensors do not require calibration and are unaffected by varying material properties, such as temperature or moisture, according to the manufacturer. Both sensor models offer single-probe designs that prevent material buildup, which can cause false signaling. The Model PZP sensor has a diamond-shaped probe that provides durability with industry-leading probe strength and excellent versatility to detect very light to heavy materials. The Model PZP offers a variety of configurations, including pipe extension, cable extension and high-temperature options. Booth 2407 — *Monitor Technologies LLC, Elburn, Ill.*
www.monitortech.com

Two-way valves to divert or converge conveyed streams

The precision-machined PST30 diverter valve (photo) is designed to prevent contamination and provide line switching for either dilute- or dense-phase conveying. The two-way PST30 valve operates as a one-to-two way diverting valve or a two-to-one way converging valve in a pneumatic conveying system for powdered or granular materials. Operation is simplified with the actuator rotating the plug forwards and backwards, which easily positions the plug to either the divert ports or the straight-through ports. The PST30 can also serve as a drop-in replacement for customers currently operating with this company's Flo-tronics PV30 valves. No changes in existing air lines or wiring are re-

quired as a result of replacement, says the company. Booth 1429 — *Schenck Process, Kansas City, Mo.*
www.schenckprocess.com/us

Custom-designed, modular bag-discharging systems

The Material Master bulk-bag-discharging system (photo) includes a scale system and a flexible screw conveyor to deliver a controlled discharge of materials through a loss-in-weight operation into users' existing processes. The unit features a scale system and a summing box, which communicates with the flexible screw conveyor to provide for an accurate discharge of material. Systems are custom-designed for each specific application. The unit utilizes a hoist and trolley system to safely load bulk bags into the Material Master system. Units are completely modular and designed to accept adaptations for future improvements and flexibility. Booth 3917 — *Material Transfer & Storage Inc., Allegan, Mich.*
www.materialtransfer.com

Conveying concepts for all types of processes

This company offers 16 different pneumatic conveying system (photo) concepts, utilizing both pressure and vacuum, for handling a wide variety of dry bulk solids. Vacuum conveying options include the models LDV 2000 and LDV 4000 (for continuous dilute-phase operations) and the HDV 6000 and HDV 8000 (for continuous dense-phase operations). Pressure conveying options include several continuous and batch options for dense-, dilute- and medium-phase conveying. Booth 1405 — *Dynamic Air Inc., St. Paul, Minn.*
www.dynamicair.com/systems

Process signals from up to 15 sensors with this system

The Watchdog Super Elite system (WDC4; photo) processes signals from up to 15 sensors for belt speed, belt misalignment, continuous bearing temperature, pulley misalignment and plug conditions on bucket elevators or conveyors. When an alarm condition is detected, the system will log the details, sound an alarm and provide shutdown control of the elevator or conveyor and feeding system. The controller settings are password protected, and can be set up either directly on the LCD screen, or by a free PC software application and transferred to the WDC4 via an SD card. The Watchdog Super Elite is simple to install and set up, and it can be connected directly to a programmable logic controller (PLC) using Modbus TCP/IP protocol. The Watchdog System is approved by CSA/NRTL for Class II dust hazard areas for use in Canada and the U.S. Booth 2549 — *4B Components Ltd., Morton, Ill.*
www.go4b.com

Use this diverter valve with abrasive materials

The SK V2 two-way diverter/converger valve is the latest version this company's traditional valve designed for positive switching of material flow in pressure or vacuum conveying systems. Engineered for 50 psig maximum pressure and 400°F maximum temperature, this valve is suitable for various abrasive materials, such as cement, limestone, bentonite, fly ash, copper concentrate, barite and other pulverized or granular materials. The SK V2 valve is compatible with dilute-phase, two-phase or dense-phase applications. Three different actuators are available: motor, air cylinder and manual lever. The SK V2 valve is available in sizes ranging from 6 to 14 in. Booth 2815 — *FLSmidth Inc., Bethlehem, Pa.*
www.flsmidth.com

Easily integrate these moisture sensors into existing processes

The MCT460 online near infrared (NIR) sensor (photo) measures moisture and additional constituents in harsh conditions. The MCT460 comes in multiple configuration options for integration into existing systems. It is easily connected to closed-loop control systems or local alarms and eliminates the need for time-consuming and disruptive laboratory testing, says the manufacturer. The MCT460 is suitable for applications that handle limestone, calcium carbonate, dairy powders, corn flours, pellets, ceramics, pharmaceuticals and more. Booth 2635 — *Process Sensors Corp., Milford Mass.*
www.processsensors.com ■

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Material Transfer & Storage

Dynamic Air

4B Components

Process Sensors

Economic Indicators

2016 2017 2018

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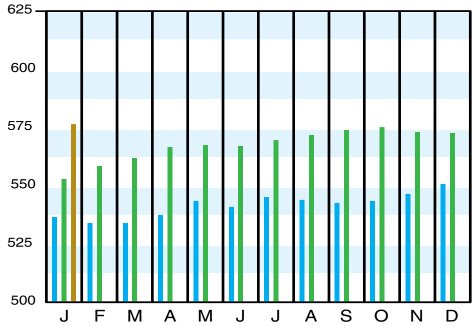
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Jan. '18 Prelim.	Dec. '17 Final	Jan. '17 Final
CE Index	576.4	572.9	553.1
Equipment	697.4	691.8	664.2
Heat exchangers & tanks	606.2	604.9	578.3
Process machinery	697.1	694.0	669.5
Pipe, valves & fittings	910.2	893.5	835.2
Process instruments	416.0	410.7	398.4
Pumps & compressors	1,001.0	996.4	971.3
Electrical equipment	531.2	524.1	512.6
Structural supports & misc.	736.1	732.7	722.4
Construction labor	328.4	330.4	324.3
Buildings	570.4	567.4	550.2
Engineering & supervision	309.2	308.9	313.5

Annual Index:
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5

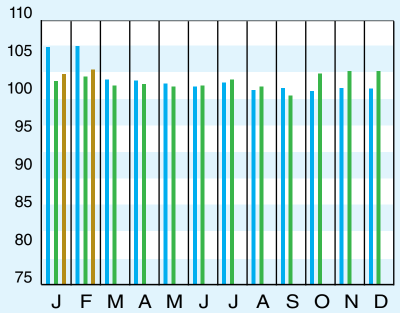


Starting with the April 2007 Final numbers, several of the data series for labor and compressors have been converted to accommodate series IDs that were discontinued by the U.S. Bureau of Labor Statistics

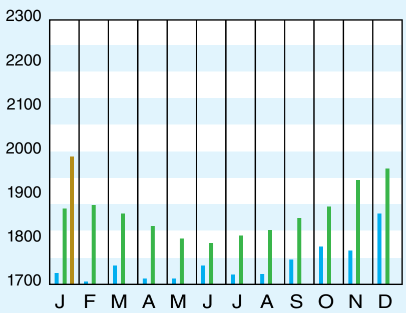
CURRENT BUSINESS INDICATORS

CURRENT BUSINESS INDICATORS	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2012 = 100)	Feb. '18	=	103.4	Jan. '18	=	102.6	Dec. '17	=	102.7	Feb. '17	=	101.2
CPI value of output, $ billions	Jan. '18	=	1,989.5	Dec. '17	=	1,970.4	Nov. '17	=	1,944.5	Jan. '17	=	1,837.8
CPI operating rate, %	Feb. '18	=	77.0	Jan. '18	=	76.5	Dec. '17	=	76.8	Feb. '17	=	76.1
Producer prices, industrial chemicals (1982 = 100)	Feb. '18	=	274.5	Jan. '18	=	267.2	Dec. '17	=	269.8	Feb. '17	=	248.4
Industrial Production in Manufacturing (2012 =100)*	Feb. '18	=	105.9	Jan. '18	=	104.6	Dec. '17	=	104.8	Feb. '17	=	103.3
Hourly earnings index, chemical & allied products (1992 = 100)	Feb. '18	=	188.2	Jan. '18	=	187.3	Dec. '17	=	184.0	Feb. '17	=	170.9
Productivity index, chemicals & allied products (1992 = 100)	Feb. '18	=	100.0	Jan. '18	=	100.8	Dec. '17	=	102.2	Feb. '17	=	101.5

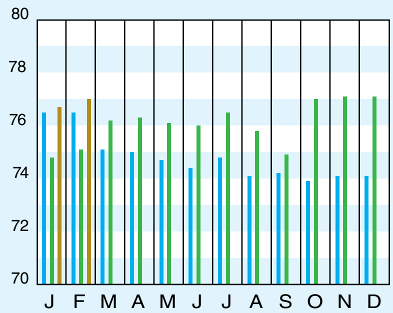
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the January 2018 *CE* Plant Cost Index (CEPCI; top; most recent available) increased compared to the previous month's value. The Equipment, Buildings, and Engineering & Supervision subindices were all higher for January, pushing the overall monthly CEPCI value for January higher. It stands at 4.2% higher than the corresponding value from January 2017. The Construction Labor subindex fell slightly in January. And because the final numbers from 2017 are now all available, the annual 2017 CEPCI value can be calculated. At 567.5, the 2017 annual index represents an increase over the 2016 annual value (541.7) by 4.8%. The annual values represent averages of the monthly values for a given year.